

7. Monitoring

Wastewater Land Application Program (WLAP) monitoring is a comprehensive program that provides information for managing and regulating WLAP sites. WLAP monitoring is determined by site-specific environmental and operational parameters.

This section presents guidance and provides the technical references that should be considered when designing a WLAP monitoring plan and establishing permit conditions for monitoring in a wastewater land application facility. General discussions of monitoring as well as particular discussions of commonly monitored media are also presented.

7.1 General Discussion

Several general considerations apply to all facilities in the wastewater land application permit (WLAP) program administered by DEQ:

- Monitoring Objectives
- Monitoring Parameters
- Monitoring Frequency
- Sampling and Sampling Location Determination
- Analytical Methods
- Quality Assurance and Quality Control
- Data Processing, Verification, Validation, and Reporting

Monitoring recommendations for commonly monitored media are provided in the following to assist in the development of a WLAP monitoring program. Each type of monitoring is discussed in a separate section and the discussion follows the outline of the general section.

Commonly monitored media include the following:

- General discussion (Section 7.1)
- Ground water monitoring (Section 7.2)
- Soil-water monitoring (Section 7.3)
- Soil monitoring (Section 7.4)
- Wastewater monitoring (Section 7.5)
- Crop monitoring and yield estimation (Section 7.6)

7.1.1 Monitoring Objectives

The goal of WLAP monitoring is to provide a timely and cost-effective assessment of both wastewater treatment process operations as well as the impact of operation and management activities on ground water, surface water, soil resources and crop health. Monitoring information provides valuable feedback to determine whether wastewater land treatment changes should be made to manage environmental impacts. All permits need to specify required monitoring sufficient to yield data that are representative of the monitored activity. WLAP monitoring requirements should have well defined objectives – i.e., it should be known how the data will be used. Useful data are generated when the purposes of monitoring are understood.

The three objectives of environmental monitoring are as follows:

a) Site Characterization

It is necessary to characterize baseline conditions of ground water, soil water, surface water, soils, and other media prior to initiation of wastewater land treatment activities and for system design purposes. Characterization of variability in monitored media, particularly wastewater and ground water, is a prerequisite to establishing monitoring schedules.

b) Site Management or Process Control Monitoring

Process control monitoring involves monitoring internal components of both the wastewater land application system and other associated wastewater treatment processes to determine whether they are functioning as designed (Crites et al. 2000). This monitoring can yield information that can be used to modify ineffective management practices.

c) Compliance Monitoring

Compliance monitoring is required in regulatory instruments so that an adequate determination of whether a wastewater-land application system is complying with applicable water quality standards, permit specific limits, and other WLAP permit conditions. Compliance monitoring includes environmental parameters, such as ground water quality. It also includes monitoring of treatment parameters, such as constituent loading, which serve as a first line of monitoring to be protective of the resource (ground water for example)

Consideration of these objectives is necessary to develop a program or strategy with the combination of monitoring that will best fit the needs of a given wastewater-land application site.

A quality assurance project plan should be written as prescribed in Section 7.1.6.

7.1.2 Monitoring Parameters

All parameters with permit limits must have associated monitoring requirements in the permit. Parameters that do not have regulatory-established limits may be included to meet clearly defined monitoring objectives as required by DEQ. Media-specific monitoring parameters are discussed in respective sections below. As will be discussed further, choice of parameters to monitor is facility-specific. Not all parameters are necessary for every site.

7.1.3 Monitoring Frequency

The frequency of sampling should result in the generation of data that provide a reasonable characterization of the media. Reasonableness can be demonstrated on the basis of the value of data collected versus cost. A primary value of the data is the establishment of data variability, an important factor in calculating permit limits, determining compliance and establishing the basis for monitoring frequency. Routine compliance monitoring frequency may be adjusted to reflect the variability - less variable parameters being sampled less frequently, while more highly variable parameters are sampled more often. The intent is to establish a frequency of monitoring that will detect most events of noncompliance without requiring needless or burdensome monitoring and associated costs.

7.1.3.1 Temporal or Spatial Variability

Variability can be temporal or spatial:

- Soils can have significant spatial variability. Monitoring considerations related to soil spatial variability are discussed in 7.4.5.2 *Sampling Location Determination*, page 7-47.
- Temporal variability of the media being monitored is one of the most important factors in establishing monitoring frequency. Therefore, the degree of monitoring frequency is dependent on the characterization of temporal variability. Various sampled media exhibit different variability. Particular parameters measured from one sampled medium can also exhibit different variability. An example of the variability over time of potato processing wastewater COD levels for one year is shown in Figure 7-1.

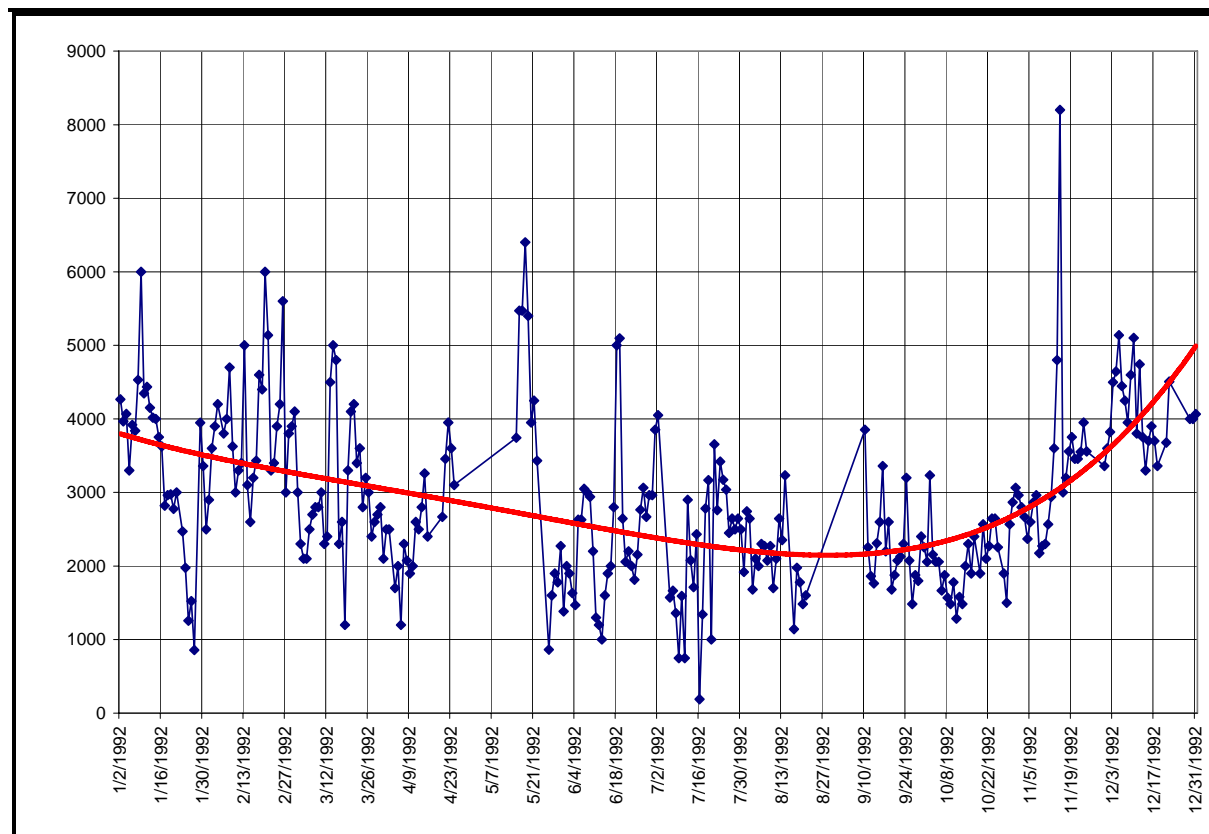


Figure 7-1. Potato processing wastewater COD levels for one year.

- Characterization of medium and parameter variability should be included as a part of the permit application (see Section 1). High frequency monitoring, usually within a tiered framework or as a special study, is recommended to characterize temporal variability of a medium. The frequencies for monitoring may be determined based on the estimated variability.

There are various statistical approaches to determining variability and sampling frequency. DEQ has developed a spreadsheet tool and explanatory text, which provides one such method for use in wastewater land treatment facility permitting. (See *Program Forms and Spreadsheets* in the appendix.)

7.1.3.2 Tiered Monitoring

Tiered Monitoring is a term used to describe a reduction or increase in frequency of monitoring required in a permit. If initial (baseline) sampling shows little variability in a parameter, a reduced monitoring scheme may then apply. Likewise, if initial (baseline) sampling indicates strong variability in a parameter, a more frequent and/or more comprehensive monitoring schedule would apply. Tiered monitoring decisions are based on the results of previous monitoring. The conditions for increase and decrease should be specified in the permit.

The triggers for the tiered elements of a permit should, where possible, be well defined in the permit and explained in the staff analysis. The permit should explain to what frequency the tiered parameter will revert if not detected, not found to be at a level of concern (a

trigger), or exceeding a level of concern. The numeric level of concern or other trigger should be defined in the permit and justified in the staff analysis. The reduction, elimination, or increase in monitoring should also be contingent upon formal notification from DEQ to the permittee of the monitoring change, be that a permit modification or written notification. Monitoring changes should be discussed with the permittee prior to formal notification.

7.1.4 Sampling and Sample Location Determination

Monitoring requirements in the permit should specify the sample type (grab, composite or continuous), and the analytical methods for each parameter. Sampling, sample handling, and analytical methods should conform to the guidance provided here and in the technical references cited.

7.1.4.1 Sampling

The sample type will depend on the following:

- The parameter to be monitored. To determine appropriate sample types, consult references provided for each respective media.
- The temporal and spatial variability of the media sampled.
- The type of regulatory limit that may be applied to sample results.

7.1.4.1.1 *Discrete Grab or Sequential Grab Samples*

A *grab sample* is an individual sample that represents "instantaneous" conditions. Use grab samples when the following is true:

- The characteristics of the media sampled are relatively constant
- The parameters to be analyzed are likely to change with storage
- The parameters to be analyzed are likely to be affected by compositing
- Information on variability over a short time period is desired
- Composite sampling is impractical, or the compositing process is liable to introduce artifacts of sampling
- The spatial parameter variability is to be determined

Another type of grab sample is sequential sampling, which is discussed in 7.5.5.1.1 Discrete Grab or Sequential Grab Samples, page 7-58.

7.1.4.1.2 *Composite Samples*

A *composite sample* consists of a series of individual samples collected over time and analyzed as one sample. Application of composite sampling to various monitored media is described in the respective media sections.

7.1.4.1.3 Continuous Monitoring

Continuous monitoring is another option for certain parameters and media, such as wastewater flow, pH, salinity and temperature; climate parameters; and soil moisture content. Important factors to remember about continuous monitoring include the following:

- Continuous monitoring is appropriate for a limited number of parameters.
- Reliability, accuracy and cost vary with the parameter.
- Continuous monitoring can be expensive, so the environmental significance of the variation of parameters of a given media should be compared to the cost of continuous monitoring equipment available.
- Continuous monitoring provides a considerable amount of data and its use should be clearly defined.

7.1.4.1.4 Other Sample Types

Several other types of samples can also be taken:

- *Split Sample* - A split sample is portioned into two or more containers from a single container. Portioning assumes adequate mixing to assure the split samples are, for all practical purposes, identical.
- *Duplicate Sample* - Duplicate samples are collected sequentially from the same source, under identical conditions, but into separate containers.
- *Control Sample* - A control sample is collected upstream, up-gradient, or away from the influence of a source or site to isolate the effects of the source or site on the particular medium being evaluated.
- *Background Sample* - A background sample is collected from an area, water body, or site similar to the one being studied but located in an area known or thought to be uninfluenced by site activities being regulated .
- *Sample Aliquot* - A sample aliquot is a portion of a sample that is representative of the entire sample.

7.1.4.2 Sampling Location Determination

The point at which a sample is collected can make a large difference in the monitoring results. The purpose of monitoring is to observe changes in conditions and compare them to expected or desired outcomes. For this reason, permanent sampling locations should be determined and identified in permit monitoring requirements. Monitoring data can then be compared without concern for spatial variability introduced under conditions where sampling locations are not permanent. The permit applicant should provide a description of all proposed monitoring locations in application materials. Important factors to consider in selecting the sampling station include the following:

- The volume of media at the sampling station should be adequate in order to obtain a sample.

- The sampling station should be easily and safely accessible.
- The sample should be truly representative of the media during the period monitored.

Additional sampling information is given in the *Handbook for Sampling and Sample Preservation of Water and Wastewater* (EPA, 1982):

<http://yosemite.epa.gov/water/owrccatalog.nsf/e673c95b11602f2385256ae1007279fe/fe398acacbde5cf685256fc1004e5680?OpenDocument&CartID=9992-112918>

7.1.5 Analytical Methods

Approved analytical methods for parameters usually include sampling and handling requirements. Media specific analytical methods are found in respective sub-sections of this section. Recommended analytical methods, in addition to information regarding sample preservation and handling, are also found in the *Ground Water and Soils Quality Assurance Project Plan Development Manual* (DEQ, 2001):

http://www.deq.state.id.us/water/data_reports/ground_water/contaminants_detected_statewide_monitoring_program.pdf

Standardization of analytical methods is important in the WLAP program, so that data can be consistently interpreted with respect to site performance and compliance with standards and/or permit-stipulated limits. Different analytical methods can yield different results: for example, a soil analysis for plant available phosphorus (P) might yield a result of 15 mg P/kg soil, while an analysis for total phosphorus (most of which is not plant available) may yield a result around 650 mg P/kg soil (Overcash and Pal, 1982; page 394). In addition, plant available phosphorus has useful agronomic interpretive value while total phosphorus does not.

Laboratory analyses have low fundamental detection limits, method detection limits (MDLs) and practical quantitation limits (PQLs):

- MDLs are the minimum concentrations that a laboratory method can measure above the instrument background noise. MDLs indicate only the minimum detection level of an analyte but do not imply any accuracy or precision in the result. As such, MDLs have little reporting value but rather reflect the standard basic capabilities of a laboratory for specified testing methods.
- PQLs are the minimum concentrations that can be reported within specified accuracy or precision criteria. PQLs can be affected by analyst skill, interferences in the sample and other operating factors. Where MDLs are typically consistent, PQLs typically vary. PQLs are always higher than MDLs, and they should be used for reporting and interpretation.

PQLs reported at or above concentrations of interest (regulatory limit, previously established lower background level, etc.) render the data useless.

For example, if the PQL for manganese (Mn) provided by a laboratory is at the ground water standard (previously the maximum contaminant level, or MCL) of 0.05 mg/L for a ground water sample, the data have no interpretive value for the entire range below the ground water standard. A method having a MDL of 0.005 mg/L, for example, would be

appropriate so long as sampling protocol minimizes interferences (e.g. minimizing turbidity in ground water samples) such that the PQL is achievable.

The tables in respective sections below provides guidance regarding chemical analytical methods recommended for environmental monitoring required in WLAP permits, including ground water, soil water, soils, wastewater, and plant tissue analyses.

Standard operating procedures regarding sample collection, preservation, storage, transportation, and preparation of samples, are also important to assure sample integrity. Recommended procedures are outlined in *EPA (Revised 1979 and March 1983)*, *Greenberg et al (1992)*, and other relevant texts.

7.1.6 Quality Assurance and Quality Control

Data gathered in WLAP monitoring programs provides information to decision makers on the quality of ground water, soils, wastewater, leachate, etc. data collected, the adequacy of operation and maintenance procedures, and the potential for land application activities to affect the environment. If decision makers are to have confidence in the quality of environmental data used to support their decisions, there must be a structured process for quality in place. A *Quality Assurance Project Plan* (QAPP) is the environmental industry standard for a structured process for quality in the collection of environmental data.

The QAPP is the single most important quality assurance tool at the project or monitoring program level, and is necessary for all data collection and generation activities. The QAPP summarizes the DQOs (Data Quality Objectives) of the project or monitoring program and integrates technical and quality aspects, including planning, implementation, and assessment into a single document.

The purpose of the QAPP is to document planning efforts for environmental data collection, analyses, and data reporting to provide a project-specific “blueprint” for obtaining the type and quality of data needed for a specific decision or use. The QAPP documents the activities that will take place during the project or monitoring program, including: field and laboratory activities; data verification and validation; data storage and retrieval; data assessment; and, project or monitoring program evaluation and process improvement. The QAPP documents how QA (quality assurance) and QC (quality control) are applied to environmental data collection activities to assure that the results obtained are of the type and quality needed and expected. QA is defined as: “An integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.” (EPA QA/R-5, March 2001). QC is defined as: “The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality.” (EPA QA/R-5, March 2001).

The success of an environmental monitoring program depends on the quality of the environmental data collected and used in decision making, and this may depend significantly on the adequacy of the QAPP and its effective implementation. Data users, data producers, and decision makers should be involved in the QAPP development process

for their monitoring program to ensure that their needs are adequately defined and addressed in the QAPP.

7.1.6.1 QAPP Development and Submittal Guidance

The permittee's QAPP should be developed to comply with EPA QA/R-5 *Requirements for Quality Assurance Project Plans* EPA/240/B-01/003, March 2001. QA/R-5 allows flexibility in the degree of rigor to be applied via the QAPP depending on the type of environmental monitoring to be performed, the intended use of the data, and the risk involved in using data of uncertain quality. Section 7.7.2 lists the content elements that should be addressed and included in a QAPP according to QA/R-5. The permittee's QAPP for a monitoring program should be submitted by the permit applicant as part of the application material for review and approval by DEQ.

7.1.6.2 Quality Control (Q/C) Samples for Monitoring

QC procedures should be described in the QAPP as they relate to the use or taking of QC samples during data collection activities. Field duplicate samples should be taken at a minimum rate of 5% (one duplicate for each 20 samples collected) or one duplicate per sampling event, whichever is less, to provide for determining field sampling precision. A field or equipment blank (rinsate blank) should be taken, one for each sample delivery group. Rinsate blanks shall be analyzed to determine if in-field equipment decontamination procedures are adequate. Trip blanks should be taken if there is reason to believe that a possibility of cross contamination may exist. Trip blanks provide a means to check sample collection, handling, and shipping methods to determine if cross contamination is occurring during those activities.

Laboratory QC samples should also be addressed in the QAPP and should be as specified in the applicable analytical method.

7.1.7 Data Processing, Verification, Validation, and Reporting

Data processing, data verification, and data validation are quality assurance tools used to determine if data has been collected as specified in the QAPP with respect to compliance, correctness, consistency, and completeness. In addition, these tools are used to assess the technical usability of the data with respect to the planned objectives or intention of the project or monitoring program. Although these tools are really processes, project or monitoring program specific measurement criteria for the data processing, verification, and validation should be determined during project or monitoring program planning and documented in the QAPP.

Data Processing includes data entry, validation, transfer, and storage. The QAPP should describe or reference specific procedures used to maintain the integrity of the data records as well as any project or monitoring program specific data storage/transmittal requirements. This process includes data formats and standards for the transfer of data to external data users. Specific data processing activities may include:

- **Collection:** For both manual data and computerized data acquisition systems, internal QC checks should be developed and implemented to avoid errors in the data collection process.

- **Transfer:** Data transfer steps should be minimized and procedures established to ensure that the data is free from errors and is not lost during transfer.
- **Storage:** At each stage of data processing, procedures should be established to ensure that data integrity and security are maintained. The QAPP should indicate how specified types of data will be stored with respect to format, media, conditions, location, retention time, and access.
- **Reduction:** Data reduction includes any process that changes either the form of expression, the numerical value of data results, or the quantity of data. This includes verification, validation, and statistical or mathematical analysis of the data. Reduction is distinct from data transfer in that it entails a change in the dimensionality of the data set. Procedures for verifying the validity of the reduction process should be described in the QAPP.

Data Verification refers to the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or permit requirements. It focuses on determining that the data have met the measurement requirements. Verification evaluates the data for basic elements such as sampling the correct sites, sample handling, chain-of-custody procedures were followed, QAPP specified analytical methods were used, the appropriate parameters were analyzed, etc. Data verification is not concerned with evaluating or assessing the quality of the data set.

Data Validation is an analyte and sample specific process that extends the evaluation of data beyond method, procedural, or permit compliance (i.e., data verification) to determine the analytical quality of a specific data set. Data validation criteria are based on the data quality objectives or measurement quality objectives specified in the QAPP.

Additional information and specific guidance and procedures for data verification and data validation can be found in the following EPA documents:

- Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8 EPA/240/R-02/004, November 2002)
- EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA540/R-99/008 October 1999)
- EPA Contract Laboratory Program National Functional Guidelines for inorganic Data Review (EPA540/R-01/008 July 2002)

The first document above, and other EPA quality assurance requirements and guidance documents can be found at this EPA web site:

http://www.epa.gov/quality/qa_docs.html

The second and third documents above can be found at this EPA web site:

<http://www.epa.gov/oerrpage/superfund/programs/clp/guidance.htm>

Data Reporting requires that operational, wastewater quality and ground water quality records be maintained. Permits require that this information be reported to the DEQ State Office and to the appropriate DEQ Regional Office. The reporting frequency may be

monthly, annual, or may correspond either to the frequency with which the information is collected or as required in the WLAP permit. Permits generally require that all monitoring data collected for required parameters be reported, even if collected at frequencies above that required in the permit. This requirement is meant to help guard against the potential of reporting bias if only certain results out of a greater pool of results are reported. If parameters other than those required in the permit are monitored, these results are not required to be reported.

It is critical that data be given to DEQ in a format suitable for the data's intended use. In all cases, the data must be presented in an organized and clear manner, and if necessary, supporting data may be required (e.g., duplicate measures, spike recoveries, etc.). The data collected as required in the permit should be submitted to DEQ in the *Annual Report* in a standardized electronic Excel spreadsheet format. This spreadsheet and accompanying instructions may be obtained from DEQ by request; they are generally provided during the permit application, issuance and renewal process.

The Annual Report is submitted to DEQ on a regular schedule stated in the permit. Special reports may be required in a permit, which frequency and format should be specified in the permit.

The monitoring data required in the permit is taken from the annual report and entered into a computerized database. This database is called the WLAP Information Management System (WLAP-IMS). The WLAP-IMS, when fully developed, will be able to generate compliance reports as well as data analyses of ground water, soils, soil water, loading rates, wastewater chemistry, trend analyses etc.

7.1.8 References

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- EPA. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-CI), EPA-600/4-79-020. Methods for Chemical Analysis of Water and Wastes. Revised March 1983 and 1979 where applicable.
- EPA. U.S. Environmental Protection Agency. 1973. Handbook for Monitoring Industrial Wastewater.
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- Keith, L.H. 1991. Environmental Sampling and Analysis: A Practical Guide. Lewis Publishers, Inc., ISBN 0-87371-381-8, 129 pp.
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7.2 Ground Water Monitoring

This section describes the elements of a ground water monitoring plan for wastewater land treatment facilities. (It is beyond the scope of this section to address monitoring of sites having hazardous or radionuclide constituents.)

Ground water monitoring provides data that can be used to evaluate a facility's impact on ground water as well as evaluate ground water quality changes with respect to changes in wastewater land treatment management and loading changes. Ground water monitoring also serves to assess compliance with a wastewater land application permit, including ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200) and/or permit specific limits. Ground water monitoring is necessary in most circumstances to define ambient conditions and establish a water quality baseline for the facility. Ground water monitoring often plays a major role in evaluating and modifying treatment processes, management, and loading practices to protect and maintain ground water quality.

The need and level of ground water monitoring is dependent upon facility type and size, wastewater characteristics, management, loading rates, and aquifer and site characteristics. For example, a small facility with low strength wastewater loaded at low rates would have a limited potential to contaminate ground water and may not need as extensive a monitoring program as larger and more complex facilities land applying high strength wastewater at high rates.

7.2.1 Alternatives to Ground Water Monitoring

There are circumstances where ground water monitoring may not be necessary, as in the case where wastewater constituent loading rates are *below levels of regulatory concern* (i.e., *de minimus* rates).

Although monitoring wells are the primary means of assessing ground water quality associated with land treatment systems, there are situations where their use would be impractical, such as in cases where there are long unsaturated and or saturated contaminant travel times (as a result of deep ground water, low percolate generation, and/or low

permeability of vadose zone). In those cases, the time interval between land use activities and environmental response would be too large to provide timely feedback for management or compliance purposes.

Short, moderate, and long travel times are subjective, depending on the context. In a regulatory context, a long travel time might be considered to be the length of a typical 5-year permit. It could be considered *untimely* if the impacts from a management activity could not be detected through ground water monitoring beyond the life of the permit.

Other means to assess potential environmental impacts, such as soil-water monitoring, should be considered in such cases. (See Section 7.3 for additional discussion on soil-water monitoring. A simple method of estimating travel time through the vadose zone is presented by 7.7.5.2.3.)

Alternatives to ground water monitoring are considered on a case-by-case basis. A decision flowchart (7.7.1.1) serves to help determine whether ground water monitoring is practical and/or needed at a wastewater land treatment site. In general, ‘de minimus loading rates’ referred to in the flowchart are loading rates, which pose no regulatory concern. Specific numerical loading rates have yet to be defined and may be facility specific. The reference to *Guideline Loading Rates* refers to those generally recommended loading rates (nutrients, COD, hydraulic etc.) found in Section 4 of this guidance.

7.2.2 Monitoring Objectives

The purpose of ground water monitoring is to determine whether wastewater is being land applied and treated such that the waters of the state are protected for existing and projected future beneficial uses. Monitoring wells are preferred over other types of wells for collection of ground water quality samples. They can be located in a specific location and they can be constructed to monitor specific zones within an aquifer to isolate particular contaminants. Monitoring wells are installed specifically for assessing ground water quality.

Existing wells may be used for ground water monitoring only if the well is properly located, constructed and it is screened in the appropriate interval necessary to monitor the appropriate aquifer and the constituents of concern. Existing wells should be evaluated using the criteria provided below. Exceptions to these criteria may be made by DEQ on a case-by-case basis:

- The well is located within a reasonable distance from the wastewater land treatment facility to provide relevant ground water quality information.
- The well meets the construction requirements outlined in IDAPA 37.03.09.
- The well is completed in the uppermost aquifer.
- The screen length is appropriate for the hydrogeologic conditions and monitoring the constituents of concern.
- The well will yield water quality samples representative of background or other relevant water quality conditions.
- The water quality is not degraded by an activity between the well and the wastewater land application facility.

- The well is approved for use by DEQ.

7.2.3 Monitoring Instrumentation

This section provides guidance on monitoring well design and construction practices for wastewater land application facilities. This monitoring well construction guidance is not applicable for sites where hazardous materials are known to exist.

Monitoring wells should be designed to sample the uppermost ground water potentially affected by the activity plus any other ground water zone where contaminants may impact ground water quality. The number of wells installed should be sufficient to adequately assess background water quality and the impacts to ground water as a result of wastewater land treatment activities. Monitoring well construction is a critical component of the monitoring plan since background water quality data are used to establish baseline levels, and possibly site specific permit limits and early warning values. Each monitoring well should be designed and constructed for the specific hydrogeologic environment and the contaminants of concern.

Several goals should be achieved in monitoring well construction:

- Construct the well with minimal disturbance to the formation.
- Use materials compatible with the geochemical environment.
- Complete the well within the zone of interest.
- Adequately seal the borehole with materials that will not influence the quality of the samples.
- Sufficiently develop the well to remove additives introduced during drilling and allow unobstructed flow through the well, (EPA, 1991b).
- Construct the well in such a manner that contamination from the surface will not migrate along the sides of the borehole and ensure that well is sealed properly to prevent cross contamination from other aquifers

Some general guidelines should be considered during the construction of any monitoring well. The most important of these address the following:

- regulatory requirements
- drilling methods
- screened interval
- casing materials
- seals, packing and grouting
- well development

7.2.3.1 Regulatory Requirements

All monitoring well construction must conform to the well construction rules listed in the *Idaho Administrative Procedures Act* (IDAPA) 37.03.09. Monitoring wells more than 18 feet in vertical depth that are constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristics of the ground water or aquifer require a permit to be issued by the *Idaho Department of Water Resources* (IDWR). Monitoring wells 18 feet deep, or less, also should conform to the well construction rules listed in IDAPA 37.03.09

Siting of monitoring wells in relation to a wastewater land treatment site and other possible sources of contamination should be coordinated with DEQ as part of the WLAP permitting process. Proposed monitoring well designs should be submitted to DEQ for review and approval prior to well construction.

Certification that monitoring well construction is in substantial accordance with proposed monitoring well design should be submitted to DEQ. Such certification may consist of as-built diagrams stamped by an Idaho registered Professional Geologist or Professional Engineer, or prepared by someone under the direct supervision of an Idaho registered Professional Geologist or Professional Engineer. A detailed geologic log for each monitoring well should also be provided to DEQ.

7.2.3.2 Monitoring Well Construction

Specific installation procedures for ground water monitoring wells may be found in the Idaho Administrative Code, Department of Water Resources, *Well Construction Standards Rules* (JAC 2005); Ogden (1987); DEQ (March 2001); EPA (1991b); and EPA (1986a). Additional guidance is available from ASTM D 5092-90.

Details regarding the construction of monitoring wells are found in 7.7.3.1. Included in this appendix are discussions of drilling methods; selection of screened interval depths; casing materials; seals, packing and grouting; and monitoring well development.

7.2.3.3 Monitoring Well Protection and Maintenance

The area around groundwater monitoring wells must be protected. Several practices may be employed for this. Highly visible markers may be used to warn equipment operators of the presence of the well. Using posts cemented into the ground to surround the well offers added protection against a well being damaged by equipment.

Damage from equipment includes cracked grouting, cracked or broken well piping, or broken locks or casings. This type of damage can result in the intrusion of surface water into the well and the contamination of groundwater. Such a well may have to be abandoned and another well constructed, at additional time, expense, and loss of data continuity.

Monitoring wells should be regularly maintained. Maintenance should include ensuring that caps are rust-free and locked at all times, that the outer casing is upright and undamaged, and that there is clear, unobstructed access to each well.

7.2.4 Monitoring Parameters

Table 7-1 provides general guidance for ground water monitoring analytical parameters for selected wastewater land treatment scenarios. In general, well below guideline loading rates (WBGLR) , referred to in the table, are loading rates that pose no regulatory concern. Specific numerical loading rates have yet to be defined for the WBGLR designation and may be facility specific. The reference to *Guideline Loading Rates* refers to those generally recommended loading rates (nutrients, COD, hydraulic etc.) found in Section 4 of this document. Microbiological parameters may be needed on a site-by-site basis.

Table 7-1. Common Ground Water Monitoring Analytical Parameters for Wastewater Land Treatment Facilities.

Facility Type — Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Common Ions¹	O ³	O	X	O	X	X
Field Parameters²	O	X	X	O	X	X
Static Water Level	O	X	X	O	X	X
NO₃-N + NO₂-N	O	X	X	O	X	X
Fe	O	O	?	O	?	X
Mn	O	O	?	O	?	X
TDS	O	O	X	O	X	X
COD	O	O	O	O	?	X
P	O	O	?	O	?	X
K	O	O	O	O	?	X
Cl	O	X	X	O	X	X
TC	O	?	?	O	?	?

Notes:

1. Common ions consist of the following ions: Na, K, Ca, Mg, SO₄, Cl, CO₃, HCO₃
2. Field Parameters consist of the following: pH, temperature, electrical conductivity, and dissolved oxygen
3. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.
4. TC = total coliform

7.2.4.1 Contaminants of Concern: Nitrate, Iron, Manganese, TDS and Phosphorus

Wastewater sites, if not properly loaded and managed, may impact ground water. Typical contaminants of concern include nitrate, total dissolved solids, phosphorus, metals (iron and manganese in particular). The following sections briefly discuss these constituents.

7.2.4.1.1 Nitrate

Nitrate is a primary ground water constituent, meaning there can be health related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01a). The ground water standard for nitrate-nitrogen is 10 mg/L. Nitrate contamination at wastewater land treatment sites usually results from nitrogen overloading. Other contributing factors include aquifers with low transmissivity that do not provide the dilution volume, and so magnify the nitrogen (or other constituent) inputs from percolate.

High nitrogen loading of certain wastewaters such can often result in *low* nitrate levels in ground water. This is due to the influence of associated high loadings of chemical oxygen demanding (COD) constituents – generally organic materials. High COD loadings depress the redox state of the soil and reduce nitrate to atmospheric nitrogen or other nitrogen oxides which are lost to the atmosphere. See Section 4 for further discussion of nitrogen chemistry in the environment. Health risks associated with excessive nitrate ingestion include blue baby syndrome (methemoglobinemia) and are discussed at the following DEQ website:

http://www.deq.state.id.us/water/prog_issues/ground_water/nitrate.cfm

7.2.4.1.2 Total dissolved solids (TDS)

TDS is a secondary ground water constituent, meaning there can be aesthetic related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01b). The ground water standard for TDS is 500 mg/L. TDS is a general term that has different interpretations depending on the media it is measured. In ground water, TDS is generally consists of inorganic salts. In wastewaters, TDS can include significant amounts of dissolved organic material. The organic TDS fraction is higher in wastewaters having higher organic constituent levels. When modeling impacts of TDS loading to ground water, it is critical to make some other measure of the inorganic constituents in wastewater to accurately assess the inorganic fraction of TDS. Such measurements include non-volatile dissolved solids (TDS less volatile dissolved solids) or total inorganic dissolved solids (TDSI, the sum of cations and anions in appreciable concentrations). Fixed dissolved solids (FDS) is another analysis which yields the inorganic content of wastewaters (Brown and Caldwell et al., 2002 p. 10-10)

TDS can often be significantly elevated down gradient of wastewater land treatment sites, especially industrial sites. Care must be taken in the interpretation of data to account for other sources of contamination as well. An effective geochemical analysis technique involves the examination of common ions, discussed in Section 7.1.4.3, to characterize chemical signatures of background, and percolate and wastewater sources to determine causes of ground water contamination.

7.2.4.1.3 Phosphorus

Phosphorus has no numeric ground water standard (IDAPA 58.01.11.200). Phosphorus loading and monitoring guidance is described in Section 4. It is a relatively immobile constituent. Concentrations in soil water and ground water are governed by complex chemistry involving sorbed, fixed (covalently bonded), precipitated, organic, and plant

available pools. Elevated phosphorus in down gradient ground water can signal breakthrough of wastewater through coarse vadose material – possibly from excessive lagoon seepage or breakthrough from soils that have been loaded to capacity. This is discussed further in Section 4.

7.2.4.1.4 *Metals (General)*

The ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200.01ci) and the drinking water standards as specified in the *Idaho Rules for Public Drinking Water Systems* (IDAPA 58.01.08.50.01) establish criteria for total metals. Total metals analyses are used to provide an indication of the metals concentration which is available for human consumption. Drinking water wells are designed to maximize water production and minimize sediment intake whereas monitoring wells are designed to monitor changes in ground water quality. Monitoring wells are not designed to produce water for human consumption. The screened interval may not be placed in the most productive part of the formation, rather it is placed in the zone where contaminants are expected to be present which may be in a formation with finer grained sediment.

Total metals analysis measures both the metals dissolved in ground water, and metals which may be sorbed to clay or colloid sized particles suspended in ground water. Upon acidification of a ground water sample for preservation, sorbed or otherwise non-dissolved metals may solubilize. The suspended fraction may be a result of metals from the well casing (metal casing material is not approved for monitoring wells), from collected sediment within the well, or sediment from the formation. A total metals analyses may yield much higher values when wells are placed in low hydraulic conductivity formations or when well development has not been properly completed. Dissolved analyses are generally more useful in evaluating the impacts of a wastewater land treatment on ground water quality, since it considers only the fraction, which are not from anthropogenic sources.

The question arises whether metals in ground water should be evaluated using the total or the dissolved fraction. On one hand, only dissolved metals truly migrate in ground water and therefore measuring total metals skews the analytical result by including metals which are adsorbed onto particles of sediment which may only be present in the well due to poor well construction or from a silty formation. On the other hand, total metals not only represent drinking water criteria, but that metals may also move by colloidal transport in ground water, thereby making the total fraction necessary to completely characterize ground water contamination.

If metals are identified as constituents of concern, it is recommended that both total and dissolved metals be analyzed. Dissolved metals should be used to interpret geochemical changes in ground water in relation to wastewater land treatment activities. Water samples analyzed for the dissolved fraction of metals should be filtered in the field, using a filter with a pore size of 0.45 microns and preserved with nitric acid prior to submission to the laboratory.

Another alternative is to measure total metals while using *low flow purge and sampling techniques* recommended by Puls and Powell, (1992). These techniques provide a characterization of both the dissolved fraction and the portion which moves by colloidal transport in ground water. Low flow pump rates allow water from the ground water formation to move into the well while overlying stagnant zones are undisturbed. In order to

minimize sample disturbance during collection, a low flow rate of 0.2 to 0.3 liters/minute (not using a bailer) should be used for ground water samples collected for metals analysis with no filtration. Puls and Powell (1992) demonstrated no significant difference in metal concentrations between filtered and unfiltered samples when low flow rates were used. This provides an assessment of both the dissolved and mobile particulates associated with metals transport in ground water.

7.2.4.1.5 Metals (Iron and Manganese)

Iron (Fe) and manganese (Mn) are secondary ground water constituents, meaning there can be aesthetic related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01b). The ground water standards for iron and manganese are 0.3 mg/L and 0.05 mg/L respectively. Iron and manganese are often found in ground water down gradient of highly loaded wastewater land treatment facilities. Associated high COD loadings and depressed redox conditions generated in the soil can reduce the valence state of iron and manganese naturally present in soils to soluble forms (see Figure 7-2.) These reduced species are mobile and can leach to ground water. Maximum contaminant levels for iron and manganese are relatively low, being 0.3 mg/L and 0.05 mg/L respectively. See Section 7.1.3.3 for further discussion. Elevated levels of iron and manganese cause aesthetic damage such as staining of kitchen and bathroom fixtures, siding and brickwork of dwellings, and other related damage.

REACTION	Eh AT pH 7 (V)	MEASURED REDOX POTENTIAL IN SOILS (V)
O₂ Disappearance $\frac{1}{2} \text{O}_2 + 2e^- + 2\text{H}^+ = \text{H}_2\text{O}$	0.82	0.6 to 0.4
NO₃⁻ Disappearance $\text{NO}_3^- + 2e^- + 2\text{H}^+ = \text{NO}_2^- + \text{H}_2\text{O}$	0.54	0.5 to 0.2
Mn²⁺ Formation $\text{MnO}_2 + 2e^- + 4\text{H}^+ = \text{Mn}^{2+} + 2\text{H}_2\text{O}$	0.4	0.4 to 0.2
Fe²⁺ Formation $\text{FeOOH} + e^- + 3\text{H}^+ = \text{Fe}^{2+} + 2\text{H}_2\text{O}$	0.17	0.3 to 0.1
HS⁻ Formation $\text{SO}_4^{2-} + 9\text{H}^+ + 8e^- = \text{HS}^- + 4\text{H}_2\text{O}$	-0.16	0 to -0.15
H₂ Formation $\text{H}^+ + e^- = \frac{1}{2} \text{H}_2$	-0.41	-0.15 to -0.22
CH₄ Formation (example of fermentation) $(\text{CH}_2\text{O})_n = n/2 \text{CO}_2 + n/2 \text{CH}_4$	—	-0.15 to -0.22

Figure 7-2. Redox potential and its effect on the chemistry of soil constituents. Bohn et al. 1979.

7.2.4.2 Other Constituents

There are constituents that do not have ground water standard criteria in IDAPA 58.01.11.200, but which are nonetheless important to monitor in ground water. Certain of this constituents, such as COD and potassium, can serve to corroborate (i.e. support with additional evidence) the cause of constituent of concern impacts from certain wastewater

land treatment practices. Other constituents serve to characterize the chemical signature of ground waters or indicate the chemical stability of the sample during the sampling event.

7.2.4.2.1 Chemical Oxygen Demand (COD)

It is typical to see COD at low levels in ground water. Sulfides and other reduced constituents will appear as an oxygen demand. COD can appear at elevated levels in down gradient ground water – usually at wastewater land treatment facilities with high COD and hydraulic loading. This serves to corroborate that COD loadings are at rates higher than the soil can filter and soil microorganisms can oxidize. It also can indicate breakthrough of wastewater to ground water, as in an excessively leaking storage structure.

7.2.4.2.2 Potassium

As with COD, potassium does not have a ground water standard, but its presence at elevated levels down gradient of potato processing facilities can indicate impacts from wastewater land treatment. For example, there are appreciable levels of potassium in potatoes. Potassium is released to wastewater upon processing of the potato and is subsequently land applied. Usually there are no other significant sources of potassium to account for the elevated levels seen down gradient. Thus, it is a corroborating constituent.

7.2.4.2.3 Major Cations and Anions

The chemical characterization of ground water quality is important when making a determination of the impacts a wastewater land treatment may have on background water quality. Ground water typically has naturally occurring concentrations of major cations and anions. Major cations and anions may not necessarily be considered constituents of concern, but data collected before and during the operation of the facility can be compared to help assess environmental impacts, (Pennino, 1988).

Major cations and anions for which analyses are typically done are shown in Table 7-2.

Table 7-2. Cations and anions for which analyses typically done.

Cations	Anions
Calcium	Bicarbonate
Magnesium	Carbonate
Potassium	Chloride
Sodium	Sulfate

Natural ground water has a distinct chemical composition, which is characteristic of the geologic formation. Minerals are dissolved in solution as they migrate through the geologic formation. Major ions can be illustrated by using graphical tools such as Stiff Diagrams or Trilinear Plots to characterize the signature of the ground water. Chemical characterization also serves in identifying cross flow between aquifers and mixing within wells. Ionic

characterization data can be used to detect water quality changes and trends which may be attributed to the influence of a wastewater land treatment activity.

Common inorganic constituents can be found at elevated concentrations in most contaminant plumes. Chloride, sulfate and nitrate have a high solubility and tend to move at a similar velocity as ground water.

Inorganic constituents provide a check on the reliability of the analyses with a cation-anion balance. This is the most fundamental quality assurance/quality control (QA/QC) procedure. All waters have an equal balance of negatively and positively charged ions. The calculated error between anions and cations is generally higher for lower TDS waters. As a general rule, the sum of cations should not differ from the sum of anions by more than 2 to 3 percent. If the ratio of cations to anions does not balance, the problem is usually a typographical or analytical error; however, it can also indicate the presence of an unusual constituent which was not included in the analysis. Cation/anion analytical results with a difference of greater than 5% should be questioned. It may be an indicator that other analyses may be skewed and should be investigated for possible errors. If the relative difference between the cations and anions is small, then it is safe to assume that there are no errors in the inorganic constituents, (Hem, 1989).

Another QA/QC check is a comparison of the calculated versus the analyzed total dissolved solids values. DEQ generally has facilities analyze ground water for the major cations and anions once before permit issuance, and again near permit expiration. These analyses provide important information to evaluate impacts to ground water quality.

7.2.4.3 Field Parameters

Field parameters are ground water parameters which can be easily and accurately measured in the field with portable electronic instrumentation. These include pH, electrical conductivity, temperature, dissolved oxygen and redox potential.

These field measurements serve to:

- verify when effective well purging has occurred and when ground water has stabilized to assure that the ground water sampled is representative of water in the aquifer,
- verify laboratory measurements and can indicate sample deterioration, and,
- detect abnormalities, and they can be indicative of ground water contamination, (Davis, 1988).

The preferred method of measurement is with a flow through cell which operates at the land surface and is not introduced into the borehole. If this technology is not available, then these measurements should be taken at the wellhead. Although in-situ measurements eliminate interference caused by the atmosphere, there are other interferences which may influence field measurements more dramatically. Therefore, it is recommended that field parameters be measured with a flow through cell at the land surface, or at the wellhead, (Garner, 1988).

Field measurements should stabilize to within 5% variation per casing volume removed during well purging prior to collecting ground water samples. Readings of pH, electrical

conductivity, and temperature often stabilize within one casing volume while other chemical constituents take longer to stabilize. Dissolved oxygen is a better indicator of ground water stabilization since it can indicate the redox state of inorganic constituents (Puls and Powell, 1992). Dissolved oxygen is a critical field parameter to determine when representative ground water is entering the formation. Therefore, dissolved oxygen should be included in the suite of field parameters.

Redox potential is also a field parameter which provides important information on whether the ground water is in either an oxidizing or reducing condition. Field measuring devices for redox potential are not as accurate as certain laboratory methods. A qualitative method for determining reducing conditions is the use of the 2,2'-dipyridyl test, which indicates the presence of ferrous iron. A positive test indicates that anaerobic conditions are present which may result in the mobilization of metals. This test is simply a screening tool. A few drops of a 0.1% 2,2'-dipyridyl (or 1,10 phenanthroline) solution added to a ground water sample will cause a bright red or pink reaction if ferrous iron is present, which is indicative of a reducing environment, (Heaney and Davison, 1977), (Childs, 1981). When ground water is in a reducing environment, then the sample should be field filtered rather than filtering the sample at the lab. Total digestion analysis should be requested. Metals may co-precipitate in oxidizing conditions due to a change in redox after filtration. Sampling of field parameters is discussed further in 7.7.4.1.3.

7.2.5 Monitoring Frequency

Monitoring frequency is critical to assure that samples will detect contamination if it is present, while still assuring discrete, independent samples. The frequency of ground water monitoring should be determined on a site specific basis. Factors that should be considered include information from hydrogeologic investigations, wastewater land management and loading rates, and facility type. Statistical variability of water quality data is also critical to determining monitoring frequency. For example, the maximum error about the mean, and confidence interval one is willing to accept, will determine the number of samples one needs to take in a given time period. Statistical evaluation of ground water data is discussed further in Taylor, 2003.

Monitoring frequency for compliance can be adjusted during the permit cycle. It may be decreased if it can be determined that background and seasonal variations in ground water quality have been characterized and the data supports that a less frequent sampling interval will not miss significant periods over which elevated levels may be present. Certain parameters may be monitored on a less frequent basis if reasons exist which justify less frequent monitoring. Proper well purging and sampling techniques are especially critical when samples are collected on a less frequent basis, such as annually or biannually (Barcelona et al. 1989).

Special provisions should be made for acreages being developed for wastewater land treatment. If possible, ground water monitoring should be conducted on such sites for a sufficient amount of time in order to adequately characterize baseline potentiometric and chemical characteristics of ground water *prior to initiating wastewater land treatment activities*.

7.2.6 Sampling and Sample Location Determination

Effective monitoring requires sampling, with samples taken from pre-determined locations.

7.2.6.1 Sampling

An effective system for monitoring a land application site for potential sources of ground water contamination should be capable of detecting contamination. This is done through appropriate sampling and analysis from properly designed, located, and constructed monitoring wells. This section discusses well sampling protocols and sampling location determination.

The data collected in a WLAP ground water sampling program must be of sufficient quality to allow proper analysis and interpretation and to provide evidence for the presence or absence, extent, degree, and source of contamination. For these reasons it is essential that sampling be conducted such that the data collected are precise, accurate, representative, comparable and complete.

The goal of ground water monitoring is to sample water from the geologic formation with minimal disturbance. Representative samples should indicate the condition of ambient ground water and any changes in quality as a result of the wastewater land treatment. The facility should have a monitoring plan that includes sampling and analytical protocol to assure ground water samples will be collected and analyzed properly.

The facility is responsible for having samples collected and analyzed as required in the permit. However, DEQ reserves the right to conduct site inspections and collect samples for determining compliance. It is important to assure that the resulting analytical data will adequately represent the conditions in ground water. Therefore, it is critical that sampling and analytical protocol be properly planned to assure that the sample will not be compromised by personnel, the atmosphere, the sample container, preservatives, filtering, sampling equipment, transport, or the laboratory.

The following items should be addressed in the facility's monitoring plan:

- Sampling Supplies and Equipment
- Well purging
- Sample collection
- Decontamination
- QA/QC procedures

Specific guidance related to sampling supplies and equipment, well purging, sample collection, sample packing and shipping, and decontamination are discussed in 7.6.5.

7.2.6.2 Compliance Determination and Confirmatory Sampling

Ground water quality compliance is based on results from routine sample analysis at each compliance monitoring point identified in the facility's WLAP permit. The number of samples collected, testing frequency and constituent analysis stated in the WLAP permit are minimum requirements unless otherwise stated.

Ground water quality permit violations occur when a compliance sample analysis result exceeds a level specified in the permit whether a ground water quality standard or alternate permit limit. Permits may be written such that a first exceedance will not generate enforcement action or penalties. An exceedance may be treated as a warning signal that prompts further actions such as: assessment of wastewater management practices, evaluation of the treatment capabilities and maintenance of the land application system, and assistance from qualified experts. Statistical analyses can be utilized to determine whether there are temporal or other trends in ground water. (See Taylor, June 2003). In the event a continuing violation occurs, DEQ will determine if enforcement action is warranted.

If laboratory results from compliance sampling show an exceedance of a permit limit, then confirmatory sample collection is recommended. Confirmatory samples can validate the analytical results from the previous sample and should be taken as soon as initial exceedances are known or suspected. If confirmatory samples are not collected, then the laboratory results from the original sample may be used for compliance determination. Confirmatory sampling requirements should be included in permit requirements.

Confirmatory sampling may also be conducted and used to establish trends in ground water quality or to monitor a continuing ground water quality violation. Finally, confirmatory samples are recommended, but not required, for samples collected for purposes other than compliance.

7.2.6.3 Sampling Location Determination

A monitoring network should be designed based on the information from a hydrogeologic investigation. A properly designed monitoring network is essential. Ground water monitoring wells must be properly sited to provide areal coverage of the affected site. Wells must be constructed and sampled so as to obtain representative water quality samples. Sample variability can result from temporal and spatial variability in ground water or from influences during well pumping, purging and recharge. Therefore, monitoring well location, design, construction, and sampling should be carefully planned initially to help assure that all samples will be useful and representative of ground water quality. The monitoring plan should be facility-specific.

Monitoring well locations must be approved by DEQ prior to installation to help ensure that the wells will be sited, designed and constructed properly in order to assess wastewater land treatment impacts.

The number of wells must be sufficient to ensure a high probability of detecting contamination when it is present. Specifically the placement and number of monitoring wells will depend on both aquifer and facility characteristics. Aquifer related characteristics include the ground water gradient and the site hydrogeology. Information on ground water flow direction is essential in siting wells. Aquifer hydraulics may cause spatial and temporal variability in samples, (Barcelona et al. 1989); therefore, monitoring well locations should be carefully considered prior to installation.

Facility characteristics include the volume and quality of wastewater land applied, and the fate and transport characteristics of potential contaminants. The size and configuration of the facility and land treatment acreage are particularly important. Generally, large land application sites with complex hydrogeology may require more monitoring wells than sites

that are small or hydrogeologically simple. The number of wells also depends on the type of monitoring requirements. Land application sites with a long down gradient boundary perpendicular to the ground water flow direction may require additional monitoring wells.

Up gradient wells (un-impacted by the facility's activities) define ambient ground water quality, and are necessary to compare background water quality to down gradient water quality (water potentially impacted by the facility's activities). Ideally, up gradient wells should be located along the ground water flowpath toward the site. In Figure 7-3, wells 1, 2, and 3 are improperly located; wells 4, 5, and 6 are properly located.)

Background water quality characterization from up gradient wells will reduce the probability of attributing to wastewater land treatment any contamination originating off-site from other sources, or vice versa. At least one up gradient well is necessary to characterize background water quality.

Location and number of down gradient wells should be determined based on the designated point of compliance. Compliance wells must be located hydraulically down gradient of the wastewater land treatment site, along the flowpath of ground water discharging from the site. Down gradient wells must be reflective of the activity's impacts to ground water quality. At least two down gradient well are necessary in addition to an up gradient well to assess impacts and triangulate ground water flow.

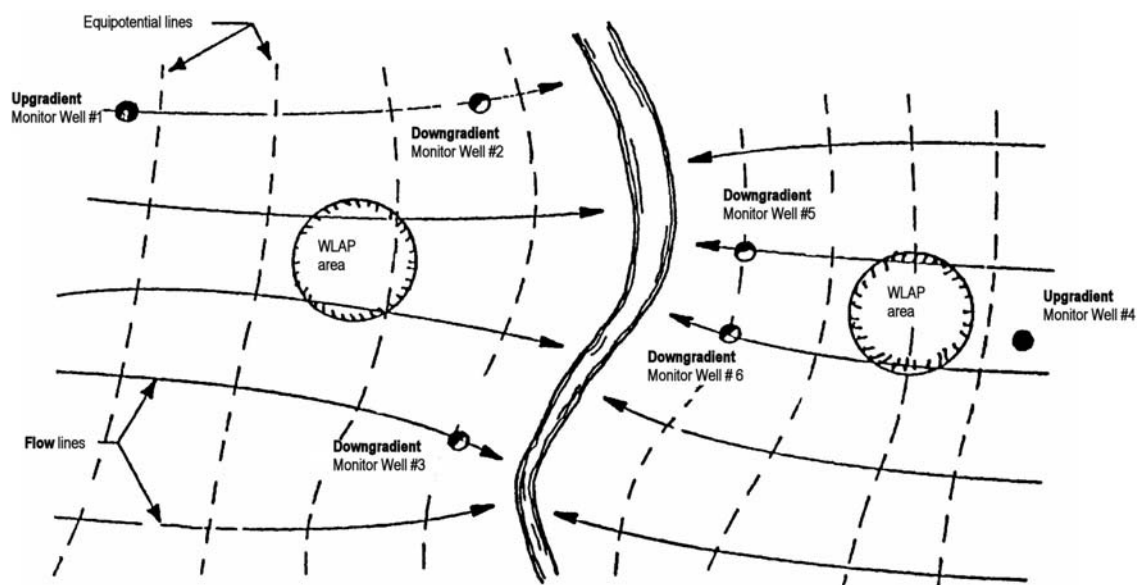


Figure 7-3. Improper and Proper Locations for Groundwater Monitoring Wells.

Ground water monitoring should be conducted in the uppermost saturated zone in addition to any other zones potentially affected by the wastewater land treatment activity. Significant water quality changes will occur in the uppermost saturated zone sooner; however, hydraulic connections between aquifers can cause contamination in lower aquifers. Ground water quality trends are determined by monitoring specific wells consistently over time.

7.2.7 Ground Water Compliance Points Monitoring

Ground water compliance monitoring involves sampling and testing ground water from approved collection points for compliance with permit conditions. Ground water compliance monitoring may not be necessary for every wastewater land treatment site (see Figure 7-5). If ground water compliance monitoring is required, compliance points for sampling and testing must be identified in the facility's WLAP permit. The number, location and frequency of sampling of compliance points are determined through the permit process.

The *point, or points, of compliance* are the locations where the facility must be in compliance with either ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200) or permit specific limits (IDAPA 58.01.11.400.05). Such standards and limits are the maximum allowable contaminant concentrations allowed at a point of compliance.

The point, or points, of compliance are determined by DEQ on a site specific basis for each facility. The point of compliance provides information to assess ground water conditions related to current and reasonable future uses of the ground water.

Ground water is typically designated as the medium where the point of compliance must be achieved since it is the primary resource which is being protected. If the point of compliance is determined to be in ground water, the following criteria should be considered in locating a point, or points, of compliance:

- The point should be as near the wastewater land treatment activity as technically feasible.
- A monitoring well must be used as the device to measure compliance.
- The monitoring wells must be located hydraulically downgradient of the wastewater land treatment activity.
- The monitoring wells must be properly constructed and screened in the uppermost ground water zone.
- If other ground water zones may be affected, then these should also be monitored by separate monitoring wells.
- The monitoring well(s) must measure the impacts of the facility's wastewater land treatment activity on ground water quality.

One well may not be adequate to measure compliance. Therefore, the point of compliance is not necessarily limited to one well, but may include an array of wells if it is determined that the information would provide a better representation of ground water conditions.

Additional wells may be required if there are multiple compliance points, if the wastewater is being land applied over a large surface area, if multiple aquifers may be affected, or if the ground water flow direction varies seasonally.

Site specific conditions may warrant setting a ground water point of compliance in an alternate location to assure protection of public health and the environment. DEQ may establish alternate ground water compliance monitoring points if provided sufficient justification. A permit limit should be established in ground water at the point(s) of compliance *unless* one of the following conditions exist:

- A monitoring well will not adequately allow measurement of the impacts a wastewater land treatment activity will have on ground water quality (e.g. screened too deep, not along down gradient flow path etc.).
- The initial point where the leachate from wastewater land treatment reaches ground water cannot be determined. For example, in fractured basalt the wastewater may move along preferential pathways making it difficult to determine the location of its entry into ground water.
- The limit established for ground water at the point of compliance is met prior to release into the environment.

If it is economically infeasible or technically impractical to locate the point of compliance in ground water, monitoring limits can be established in the vadose zone directly under the wastewater land treatment site. Modeling can be done to determine what percolate concentration for a given volume would be expected to result in ground water exceeding ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200), or permit specific limits. (See discussion in .) Thus, vadose zone monitoring can still be used to measure compliance when ground water monitoring is not feasible.

7.2.8 Analytical Methods

IDAPA 58.01.11.200.d requires that analytical procedures to determine compliance “shall be in accordance with Environmental Protection Agency, Code of Federal Regulation, Title 40, Parts 141 and 143, revised as of July 1995; or another method approved by the Department.” Table 7-19, presents chemical analytical methods recommended for ground water samples. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits are generally an order of magnitude less than the Ground Water Quality Rule (IDAPA 58.01.11.200) standards for constituents assigned such numerical limits.

7.2.9 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP) that includes instructions for field parameter stabilization. For more information on the development of a QAPP, refer to Section 7.1.6.

7.2.10 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility’s permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting ground water monitoring data, describe the well location and use the monitoring serial numbers designated in the permit.

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7.3 Soil-water (Vadose) Monitoring

The vadose zone is defined, for the purposes of this document, as occupying the soil and geologic units lying between the bottom of the root zone and the top of the water table. Water samples representing water in the vadose zone are collected with lysimeters. Monitoring of this kind is referred to in this section as *soil-water monitoring* or *vadose zone monitoring*. Vadose zone monitoring is intended to be a means of providing early detection of migrating contaminants before they reach ground water.

Definitions and characteristics of soil water are discussed in EPA (1993, Section 9). This discussion is excerpted/summarized in this paragraph. Three major types of soil water can be identified in the context of sampling soil water: (1) Macropore or gravitational water, which flows through the soil relatively rapidly in response to gravity (excess of 0.1 to 0.2 bars suction); (2) soil-pore or capillary water, which is held in the soil at negative pressure potentials (suction) from around 0.1 to 31 bars of suction; and (3) hygroscopic water that is held at tensions greater than 31 bars suction. Soil-pore water moves through the vadose zone, but at much slower rates than gravitational water, whereas hygroscopic water moves primarily in the vapor form. The term soil solute or solution sampling has been used loosely in the literature to describe most sampling methods, whereas the term soil pore liquid is typically used in a more restricted sense to apply to sampling of capillary water. The chemistry of the soil solute sample can differ significantly, depending on the sampling method used. Concentrations of inorganic species generally increase as the matric potential increases (i.e. concentration is inversely related to soil pore water volume).

Vadose zone monitoring offers certain advantages for monitoring environmental response to wastewater land treatment activities. Lysimeters are less expensive and easier to install than monitor wells. Lysimeter samples (from gravity lysimeters) reflect percolate quality after wastewater has received treatment in the root zone. Vadose monitoring can provide important information regarding potential impacts of percolate to ground water in a much more timely fashion than monitoring wells if vadose and/or aquifer travel times are long. However, a disadvantage is the difficulty both in obtaining samples on a regular basis, obtaining representative samples, and interpretation of results. Instrumentation can be unreliable. Variations in soils and other factors contribute to high variability and poor reproducibility in data obtained.

Vadose zone monitoring can be used in both a management and regulatory context. For example, a threshold soil water percolate constituent concentration can be calculated above which down gradient ground water constituent concentrations would exceed acceptable levels. Such a threshold leachate concentration can be back-calculated from assumed values of ground water flow, up gradient ground water concentration, and leachate volume. This calculated threshold percolate concentration can then be compared to sample concentration data from lysimeters for management or regulatory purposes. Further discussion of utilization of lysimeter data is found in 7.7.5.2. Further discussion of when vadose zone monitoring is appropriate is found in Section 7.1 and Figure 7-5.

The remainder of this section discusses soil water monitoring objectives, instrumentation, monitoring parameters, sampling, analytical methods, QA/QC and Data Validation. Supplemental data use and interpretation is also included.

7.3.1 Monitoring Objectives

Site and management conditions that would indicate soil-water monitoring as the preferred alternative to ground water monitoring are discussed in 7.2.1. Soil-water monitoring can serve to collect early warning information about strength and volume of percolate and its potential to contaminate ground water. This is especially useful where both depth to ground water is great and percolate travel times are long, making it impractical to wait many years for indicators of contamination to appear in ground water.

7.3.2 Monitoring Instrumentation

Instrumentation is available to 1) collect soil water samples under unsaturated conditions, 2) collect soil water samples and measure percolate loss under saturated flow conditions, and 3) measure soil water content only. These types of instrumentation are discussed below. See EPA (1993, Section 9) for further details.

7.3.2.1 Soil Water Sample Collection Instrumentation

There are two basic types of soil-water monitoring instrumentation: pressure-vacuum (suction) lysimeters (hereafter pressure-vacuum samplers) and free-gravity lysimeters. This section discusses these in addition to ‘wick’ lysimeters and another recently developed sampler.

7.3.2.1.1 Pressure-Vacuum Samplers

The pressure-vacuum samplers withdraw a soil-water sample by vacuum from the soil profile. The sample is then collected by pressurizing the sampler, which forces the water sample to the surface. One of the advantages of pressure-vacuum samplers is they can collect a soil-water sample during unsaturated soil conditions when downward movement of soil-water percolate is unlikely. These lysimeters are easy to install and, for pressure-vacuum samplers, there is no depth limitation for installation. Recently developed 'advanced tensiometers' also have no depth limitation and are described in DOE (2002).

There is the possibility of sorption or other interferences from ceramic, or other non-ceramic, cup materials through which the soil water sample must pass. Certain organic chemicals, microorganisms, volatile chemicals and metals may present problems in this regard (EPA, 1993, p. 9-3). See also further discussion in 7.3.3.

Soil water chemistry and quantity information can be valuable to assess the effectiveness of site operations but may have limited utility for compliance purposes. The data collected from pressure-vacuum samplers will allow the evaluation of soil-water quality at the time of sample collection. The constituent concentration will depend highly on the moisture status of the soil at the time of sampling. Such samples may not be representative of percolate unless the sample was taken under free drainage conditions. If the sample was taken under unsaturated conditions, the constituent concentration would likely be higher than under saturated conditions. It would be invalid to assume samples taken under unsaturated conditions represented saturated conditions.

7.3.2.1.2 Free-Gravity (Pan) Lysimeters

Free-gravity or pan lysimeters can only collect a sample when soil-water is percolating downward. The sample collected represents the quality and quantity of soil-water percolate losses below the crop root zone.

Pan lysimeters provide information for system performance and potential ground water impacts from free drainage. A disadvantage of pan lysimeters is that no sample is collected unless soil moisture is high enough to allow for percolate losses. The lack of significant percolate accumulation, under the appropriate circumstances, may also provide important information regarding the likelihood of contaminant transport. Lack of sample can also mean that by-pass is occurring.

By-pass occurs when soil water freely drains around the lysimeter. Soil matric potential (suction or tension) around the lysimeter then increases relative to the soil matric potential above the lysimeter. Soil water then flows in response to the matric potential gradient generated and often moves laterally away from the lysimeter surface and toward the freely drained soil, thus causing lysimeter by-pass.

Other disadvantages of pan lysimeters are that installation can be complex and time consuming, and location is limited to relatively shallow depths (EPA, 1993).

7.3.2.1.3 Other Soil Water Samplers

In addition to the two types of lysimeters described above, there is also the "wick" lysimeter. The wick lysimeter collects both free drainage liquid as well as liquid held at tensions up to 0.4 bars. It offers the advantage of gathering real-time samples. Further information regarding soil water monitoring instrumentation, including method description, selection considerations, frequency of use, standard methods and guidelines, and sources of additional information can be found in EPA (1993, Section 9)

A recently developed lysimeter incorporates both the ability to obtain a soil water sample as well as capacity to measure soil water flux without the complication of by-pass. The vadose zone fluxmeter with solution collection capability is described further in Gee et al. (2003).

Table 7-3 provides a summary of soil monitoring instrumentation, including the advantages and disadvantages of each method (CLFP, 2002).

Table 7-3. Summary of soil water sampling instrumentation).

Method	Description	Advantages/Disadvantages
Soil Sampling	Soil samples are collected and analyzed for pH, ECe, Cl, NO ₃ -N	<ul style="list-style-type: none"> + Simple and reliable -Samples totals, not just solution fraction -Destructive sample -Requires a soil water balance calculation to determine whether flow occurs
Suction Lysimeter	A porous ceramic tube is placed in the soil so soil solution samples can be collected and analyzed	<ul style="list-style-type: none"> + Inexpensive, simple technique to implement -Extracts soil solution that is not mobile -Known to have large measurement variability -Requires a soil water balance calculation or correlation with soil moisture to determine whether flow occurs
Pan Lysimeter	A small collection pan (1-5 ft ²) is buried at a selected depth so that soil solution samples can be collected via gravity drainage for analysis. Side wall extending above the device may improve performance	<ul style="list-style-type: none"> + Extracts soil solution during flow events + Provides a measure of both flow and water quality + Installation can approximate undisturbed conditions + Moderate variability among replicate samples -Relatively expensive installation costs -Will not result in samples in unsaturated soil
Basin Lysimeter	A large collection pan (50-400 ft ²) is constructed and covered with soil so that soil solution samples can be collected via gravity drainage for analysis	<ul style="list-style-type: none"> + Extracts soil solution during flow events + Provides a measure of both flow and water quality -Installation creates disturbed soil conditions + Large sample decreases variability -Long-term installation generally done prior to starting a project
Wick Lysimeter	A porous wick designed to match the water retention characteristics of the soil is buried at a selected depth so that solution samples can be collected using a low negative pressure.	<ul style="list-style-type: none"> + Extracts soil solution at near zero water potential + Installation can approximate undisturbed conditions -Requires a soil water balance calculation to determine whether flow occurs

From CLFP (2002)

7.3.2.2 Soil Water Measurement Instrumentation

Measurement of soil water content can be done in both the crop root zone and the vadose zone. Soil moisture measurement in the root zone is typically done for irrigation scheduling purposes. Soil moisture is often measured somewhat qualitatively to determine when sufficient root zone depletion of water has taken place to require irrigation.

Measurement of soil water content in the vadose zone for contaminant fate and transport purposes requires more quantification, and is discussed in Ley et al. (2002) and in EPA (1993, Section 9). This latter discussion is excerpted/summarized in the following two paragraphs. Water state in the subsurface is measured in terms of hydraulic head in the saturated zone and negative pressure potential or suction in the vadose zone. Water movement in the vadose zone is determined by the interaction of three major types of energy potentials: (1) matric potential (the attraction of water to solids in the subsurface), (2) osmotic potential (the attraction of solute ions to water molecules), and (3) gravitational potential (the attraction of the force of gravity toward the earth's center). Water flow in the

vadose zone is strongly influenced by the moisture content (or matric potential, which is a function of moisture content), with hydraulic conductivity and resulting flow decreasing exponentially as moisture content decreases.

EPA (1993) provides information on six major techniques for measuring soil water potential and several methods for measuring soil moisture content. The measurement of soil water potential and moisture content in the vadose zone are intimately connected, and a specific measurement technique measures either potential or moisture content. Either measurement can be used to obtain the other if a moisture characteristic curve has been developed (see EPA, 1993; Section 6.3.1). Soil water instrumentation and measurement are also discussed in an agronomic context in Ley, et al. (2002).

Porous cup tensiometers are the most commonly used method for measuring soil water potential in the vadose zone. The gravimetric method is most commonly used to measure moisture content from soil samples, and the neutron probe and gamma methods are most commonly used for in situ measurement of soil moisture. Dielectric or capacitance sensors provides accuracy similar to the neutron probe without some of the disadvantages of nuclear methods. Similarly, time domain reflectometry is becoming more widely used with the advent of commercially available units. Further information regarding soil water content measurement instrumentation, including method description, selection considerations, frequency of use, standard methods and guidelines, and sources of additional information can be found in EPA (1993, Section 6). In addition, ASTM D 6642-01 (2001) can also be consulted for quantification of soil water flux.

7.3.3 Monitoring Parameters

Table 7-4 provides general guidance for soil water monitoring analytical parameters for selected wastewater land treatment scenarios. It should be noted that certain parameters can be sampled with pan lysimeters and should not be sampled with pressure-vacuum lysimeters due to interferences from either ceramic or non-ceramic materials of the porous cup. Wilson et al. (1994), Table 26.3 summarizes potential chemical interferences of various porous cup materials. Table 26.2 summarizes physical properties of porous cup materials.

Table 7-4. Common Soil Water Monitoring Analytical Parameters for Wastewater Land Treatment Facilities

Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Common Ions¹	O ²	O	?	O	?	?
pH	O	O	X	O	X	X
Electrical Conductivity	O	O	X	O	X	X
NO₃-N + NO₂-N	O	X	X	O	X	X
Fe	O	O	?	O	X	X
Mn	O	O	?	O	X	X
TDS	O	O	X	O	X	X
COD	O	O	O	?	?	X
P	O	O	?	?	?	X
K	O	O	O	?	?	X
Cl	O	X	X	X	X	X

Notes:

1. Common ions consist of the following ions: Na, K, Ca*, Mg*, SO₄, Cl, CO₃, HCO₃. These ions help characterize the chemical signature of the percolate, which can be compared to up and down gradient ground water in the determination of potential impacts.

2. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

7.3.4 Monitoring Frequency

Frequency of monitoring should be addressed on a case-by-case basis. Lysimeters should be sampled at appropriate intervals to monitor for the changes in soil-water percolate quantity and quality. These sampling events do not necessarily need to be at regular intervals. More frequent sampling may be advisable at sites that anticipate large percolate losses within specific months, such as during the spring flush coinciding with snowmelt.

The timing of sample collection is very important to obtain representative data when using suction samplers. Pressure-vacuum samplers should be sampled to represent the largest soil-water percolate flux in order to maximize the potential to obtain samples. Sampling can be timed concurrent with irrigation and precipitation events. Timing for obtaining samples from pan lysimeters is not so critical. Percolate will accumulate in the pan lysimeter until it is sampled at the end of the quarter, or monthly, depending on the soil-water percolate storage capacity of the instrument.

7.3.5 Sampling and Sample Location Determination

7.3.5.1 Sampling

Lysimeter sampling methods are described in EPA 1993, Sections 9.2 (suction methods) and 9.3 (other methods).

7.3.5.2 Sampling Location Determination

Lysimeters for soil-water sampling should be installed below the anticipated crop root zone in order to collect percolate, which may contribute to deep drainage and potentially impact ground water. By collecting samples at this point, it is assumed that most of the treatment has already occurred in the crop root zone. This is a conservative assumption that does not account for the treatment potential in the vadose zone.

Soil-water status can vary widely over a land application site due to variations in irrigation application rates, soil hydraulic properties, and seasonally with changes in the evapotranspiration demand. The number of lysimeters on a land treatment field is dependent upon spatial and temporal variability, and acceptable quality of the data given the site-specifics and use of the data. Areas that are significantly contrasting with respect to soil type, topography, texture, and other properties should be sampled separately.

The data from each lysimeter sampling point, monitored over time, can be compared with site management to look for changes in percolate quality and volume in response to management practices, so that management/response relationships can be established. Such responses will likely be more qualitative and relative in nature.

7.3.6 Analytical Methods

Table 7-20 presents analytical methods recommended for soil water samples. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits reported by the laboratory should be significantly less than the ground water standard for constituents, which have regulatory limits.

Soil water sample volumes will vary depending on instrumentation used and time of year. It is recommended that there be a priority for testing established in the QAPP. For example, nitrate and EC require little sample volume compared with TDS, which requires about 100 ml. A reasonable priority would be to conduct nitrate-N and EC analyses first followed by COD, and TDS. Other analyses can then be added depending on the concerns of the site.

7.3.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.3.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting soil water monitoring data, describe the lysimeter location and use the monitoring serial numbers designated in the permit.

7.3.9 References

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7.4 Soil Monitoring

Successful treatment of wastewater through land application takes place through an agronomic mechanism. Soil monitoring is a basic component of wastewater-land application monitoring and is generally necessary for continued agronomic operation and management of a land application site.

The schedule for monitoring and the parameters to be measured will depend on the type of wastewater being applied. Soil monitoring is utilized for both nutrient management and characterizing soil quality. Soil monitoring is usually not utilized for compliance purposes. Section 7.7.7 discusses soil monitoring as used for grazing management purposes.

7.4.1 Monitoring Objectives

Soil monitoring has a dual purpose within the wastewater-land application program. The first is a *nutrient management* purpose, which is discussed in Section 4. Testing for macro-nutrients such as nitrogen, phosphorus, and potassium; pH; and micro-nutrients, are needed so that nutrient loading through wastewater and/or fertilizer can be managed to maximize both crop growth and the efficiency with which nutrients are being utilized. Extensive research on crop nutrient needs, crop response to fertilization given soil-specific nutrient status, crop health, and economic yield has been done by the University of Idaho Extension Service and others. Fertility guides and other publications are available which should be utilized in the management of wastewater land treatment facilities. Crops that appear unhealthy or for which production is noticeably decreased may indicate a need to further investigate the soil crop system to determine the problem area. For example, soils should be monitored for excessive wetness prior to subsequent application of wastewater (particularly

during the wet season). Excessive wetness can effect crop growth, nutrient uptake and mobility of nutrients and metals.

The second purpose of soil monitoring is to assess soil quality. This involves characterizing the chemical and physical properties of soils of wastewater-land application sites initially during site characterization as well as over time. Soil data can be used for determining initial permit loading and management conditions, or can indicate whether loading or management changes may be indicated during the permit cycle. Long term soil characterization can reflect effects of particular land use activities. Trend data of parameters such as available nitrogen, electrical conductivity, sodium adsorption ratio (SAR), concentrations of phytotoxic constituents, salinity, and concentrations of redox sensitive species (iron and manganese) can serve as indicators of excessive wastewater loading when compared to ambient levels in agricultural soils not used for land treatment. Soil quality monitoring can signal the accumulation of constituents which may constitute a risk to ground water, given leaching conditions. Soil data can then be utilized to determine appropriate loading rates and management. Monitoring of soils should also include metals and a periodic infiltration study, if SAR levels or operational observation indicate increased runoff or runoff potential.

7.4.2 Monitoring Instrumentation

Ferguson et al. (1991) provides a description of common soil sampling equipment, and is paraphrased here. The soil probe or tube is the most desirable tool for collecting soil samples. It will give a continuous core with minimal disturbance of the soil. The cores can be divided for the various depths. There should be very little contamination of subsoil sample with surface soil when using a soil probe. A soil probe cannot be used when the soil is too wet, too dry, or frozen. If the soil is frozen, the frozen layer will need to be fractured before a probe can be used. Soil probes cannot be used in soils that contain gravel.

‘The soil auger can be used in soils that are frozen or contain gravel; however great care must be taken to obtain representative samples and to avoid mixing of soil from different depths. The use of a soil auger in wet, sticky soils will result in mixing soil from different depths. A soil auger will not effectively gather dry, powdery soils. Use a soil auger only when a soil probe cannot be used.’ A spade can also be used for surface samples, but is not satisfactory for subsoil samples. ‘A post hole digger can be used for collecting deep samples, but its use requires some special techniques.’ Galvanized, brass, bronze, or soft steel equipment should not be used as they may contaminate the sample with metals which are important micronutrients (Self and Soltanpour, 2004). Stainless steel or chrome plated tools and plastic buckets are recommended. Equipment should be clean. Wiping equipment clean between samples is generally sufficient, but washing with non-phosphate detergent and a triple rinse in de-ionized water can also be done (CES, 1997). See DEQ (2001) for further details.

DEQ (2001), Appendix ‘C’ provides soil sampling SOPs (standard operating procedures). SOPs reference monitoring instrumentation. Mahler and Tindall (1990), page 3, discuss sampling equipment. EPA (1991), Section 1 provides a complete list soil sampling equipment which may be needed. Section 4 of the same document provides a description of both hand held and power driven soil sampling equipment.

7.4.3 Monitoring Parameters

Table 7-5 shows common wastewater-land application facility types and analytical parameters recommended for on-going soil monitoring. For initial characterization of baseline soil conditions, the entire suite of analyses is recommended for all facility types.

Not included in the table are other macro- and micro-nutrients which would be monitored by facility land treatment operators or agronomists as needed to determine nutrient status of constituents which are not usually of environmental concern and wastewater land treatment sites. These include sulfate, calcium, magnesium, zinc, boron, copper, chloride and molybdenum.

Table 7-5. Common Soil Monitoring Analytical Parameters for Wastewater Land Treatment Facilities

Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
pH	O ³	O	?	O	X	X
Organic Matter	O	?	X	O	X	X
NH₃-N	O	X	X	?	X	X
NO₃-N + NO₂-N	O	X	X	?	X	X
DTPA-Fe²	O	O	?	O	X	X
DTPA-Mn²	O	O	?	O	X	X
Sodium Adsorption Ratio (SAR)	O	?	?	?	X	X
Specific Conductivity	O	O	X	?	X	X
P	O	O	X	?	X	X
K	O	O	O	?	?	X
Cl	O	?	?	O	?	X
Cation Exchange Capacity¹	O	X	X	X	X	X
Texture (USDA)¹	O	X	X	X	X	X

Note: 1. Commonly done once during each permit cycle.
2. Commonly done both at the beginning and end of the permit cycle.
3. X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

A description of the analytes shown and the rationale for monitoring are provided below:

Cation Exchange Capacity (CEC): Cation exchange capacity is a measure of a soils ability to retain and exchange positively charged ions on colloidal surfaces (Bohn et al. 1979). The finer the texture (i.e. greater surface area) and the greater the OM content of the soil, the greater the CEC will generally be. The greater the CEC, the more cations, including crop nutrients, the soil can retains. Higher CEC in soils generally indicates higher fertility.

Chloride (Cl): Chloride is commonly found in municipal and industrial wastewaters. It can move substantially un-attenuated through the soil to ground water (i.e. the ion is conservative). As such, chloride is a good indicator of contaminant movement through soil. Certain industrial wastewaters can have significant chloride concentration and may be loaded at high rates to the soil. Chloride toxicity to crops may result if concentration in the soil exceeds certain threshold levels, depending on the sensitivity of the crops. The following crop tolerance ranges are given in Biggar (1981) (in meq/L of saturated extract): low – 10 to 20; medium – 20 to 25; and high – 25 to 90+.

DTPA Extractable Iron and Manganese (DTPA Fe/Mn): Plant available iron and manganese are extracted by the chelating agent diethylenetriaminepentaacetic acid (DTPA). Fe and Mn extracted by this method are in a reduced valence state (i.e. Fe^{2+} and Mn^{2+}). Soils which have been overloaded hydraulically and/or chemically (COD) may develop reducing conditions. Reducing conditions change oxidized forms of Fe and Mn naturally resident in the soil profile to mobile forms. These forms may then leach to ground water under certain conditions. The presence of high levels of the above reduced species in soils may reflect reduced soil conditions brought on by hydraulic and/or COD overloading.

High levels of soil Fe and Mn, with respect to crop utilization, typically range from 4.1 to 10 mg/kg and 2.6 to 8.0 mg/kg respectively (Stukenholtz no date).

Sodium Adsorption Ratio (SAR): Sodium Adsorption Ratio serves as an index of the potential sodium influence in the soil. SAR values above thirteen (13) classify soils as sodic or alkali (Robbins and Gavlak, 1989), have sodium as the dominant cation, and may possibly experience infiltration problems due to deflocculation of soil colloids. Certain textures of soils can become affected at values lower than 13 (David Argyle, Hibbs Analytical Laboratories, personal communication c. 1993).

Electrical Conductivity (EC): The electrical conductivity of a water extraction of a soil is an indirect measure of the salt content in the soil. High loadings of inorganic TDS may cause salt build-up in the soil leading to crop yield decreases.

Electrical conductivities of the saturated paste extract values greater than 4 dS/m indicate saline conditions in the soil. Other *proposed* limits for defining saline soils are 2 dS/m (Bohn et al. 1979). A general soil test interpretive guide from Stukenholtz Laboratory shows ECs of 0 to 1.0 dS/m being low, 1.0 to 4.0 dS/m being medium, and 4.1 to 8.0 dS/m being high (Stukenholtz, no date).

Nitrate and Ammonium ($\text{NO}_3^-/\text{NH}_4^+$): common nitrogen species which are plant available and important in determining the resident nutrient status of soils. Nitrate is very mobile in the soil and is subject to leaching. Excessive nitrate leaching may cause adverse impacts to ground water.

Organic Matter (OM): Organic matter mineralizes over time to yield plant available nitrogen. It is common in crop nutrient guides to correlate the percent of organic matter with the pounds of nitrogen which will be mineralized during the growing season. This mineralization should be taken into account in wastewater land treatment site nitrogen balance calculations. Rules of thumb vary as to the amount of nitrogen released for each percent of organic matter in the soil. Taberna (no date) cites values of 50 pounds of nitrogen per acre for each percent of organic matter released for southwest Idaho, 40 for the Magic

Valley, and 35 for eastern Idaho. Extension fertility guides take soil organic matter into account when assessing the need for nutrient addition.

Texture: Soil textures are reported in the Natural Resource Conservation Service Soil Survey reports for many areas. Soil textures can be determined in the laboratory or by manual field methods if no soil survey reports are available, or to verify existing soil survey reports. Available water holding capacity, a very important parameter with respect to non-growing season wastewater loading, is a function of soil texture. Also, cation exchange capacity is correlated with soil texture (see below). Soil textures need only be determined once, since texture is a physical property of the soil and does not normally change over time.

Phosphorus: Phosphorus is relatively non-mobile in the soil and is an essential crop macronutrients. Phosphorus is an important species which can cause eutrophication of surface waters, and associated water quality degradation problems. Phosphorus is discussed at length in Section 4.8.

Potassium: Potassium is relatively non-mobile in the soil, and is an essential crop macronutrients. Sites which are overloaded with respect to potassium not only show very high levels in the soil profile, but distinct potassium increases from ambient ground water concentrations can often be seen down gradient.

pH: pH is a measure of the acidity/alkalinity of the soil. Generally the pH of soils does not exceed 8.3, this limit reflecting the dominating effect of carbonate on the soil chemistry. When soil pH exceeds this value, a sodic soil condition may be indicated (Robbins and Gavlak, 1989). Soil pH has an important influence on availability of crop nutrients. Productive agricultural soils generally exhibit a pH range of 6.5 to 7.5.

7.4.4 Monitoring Frequency

The frequency of soil monitoring is dependant on the type of facility, wastewater land treatment management, loading rates, and site specific factors. Table 7-6 provides recommendations for soil monitoring frequencies.

In cases where soil sampling is needed, sampling in early spring is generally indicated. Early spring sampling is done to assess the nutrient status of the soil near the commencement of the crop growing season. Fertility guides can be used to interpret the result and provide recommendations for nutrient addition for the cropping year. Soil quality status (i.e. status of non-nutrient parameters affecting crop growth and/or the environment) can also be assessed through spring sampling. Comparing spring sampling data from one year to the next can be used to estimate leaching losses of constituents such as salts. If initial and final soil concentrations are known, crop ash (inorganics) uptake and removal is known, and salts applied with wastewater, irrigation water, waste solids etc. are known, leaching losses can be estimated by difference.

Fall soil sampling after the cropping season is sometimes necessary, as Table 7-6 indicates. Additional fall sampling can be useful at facilities for which nutrient budgets (particularly nitrogen) must be closely monitored. By comparing spring and fall soil nutrient status; nutrient additions from wastewater, waste solids, and fertilizer; and crop uptake and removal; one can estimate by difference the losses of a nutrient to the environment during

the growing season. In the case of nitrogen those losses would include leaching, volatilization, and denitrification. By estimating volatilization and denitrification losses, one can arrive at a growing season leaching loss estimate.

The same is true by comparing fall and spring soil nutrient status over the non-growing season, only the nutrient additions would not include fertilizer; and there would not be crop uptake and removal. One can estimate by difference the losses of a nutrient to the environment as described for the growing season. In the case of nitrogen, estimates of volatilization and denitrification may be much more tenuous because other factors, such as organic constituent and hydraulic loading and temperature, influence soil redox potential and microbial metabolic rates, which affect denitrification. This increased uncertainty makes the nitrogen leaching loss estimate more uncertain as well.

Sampling depth intervals for common types of wastewater land treatment facilities are given in the table. To characterize nutrient status for non-mobile species, such as phosphorus and potassium, crop fertility guides typically recommend sampling the 0-12 inch depth. To characterize nitrogen status, both the 0-12 inch and 12-24 inch depths are recommended.

As discussed in Section 4.2, NO_3^- is a mobile constituent. In general, shallower depths are sampled for relatively immobile nutrients. Deeper depths should be sampled for more mobile species. Depending on the type of facility, management, and loading rates, deeper layers of the soil profile should be sampled to obtain qualitative indication of movement of constituents below the crop root zone. In Table 7-6, facilities with higher loading rates, with legacy sites, and industrial facilities generally sample at depths greater than 24 inches. Recommended sampling intervals in Table 7-6 are in 12 inch increments (i.e. 0 – 12 inches; 12 – 24 inches; etc.). It is not generally recommended to select pedogenic horizons to sample; such as A, B and C horizons; since these likely occur at variable depths in a field, and may not be readily distinguishable when sampling. Also, calculating soil constituent content from concentration data is greatly simplified when a 12 inch interval is selected, as the following formula shows:

$$\text{Soil Content (lb/acre)} = \text{Soil Constituent Concentration (mg/Kg)} * 4$$

Note: The factor of 4 is approximate and appropriate for many soils, but is dependant on the bulk density of the soil.

It should be noted that if monitoring is performed more frequently than required by the permit, the results of this additional monitoring are required to be included in the annual report. If additional parameters are monitored which are not required in the permit, these data do not have to be reported.

Table 7-6. Soil Monitoring Frequency Recommendations for Common Types of Wastewater Land Treatment Facilities.

Facility Type	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Food Processing Facility ¹ (De-Minimus Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Soil Monitoring Frequency	none	Annually: Early Spring	Annually: Early Spring	Annually: Early Spring	Annually: Early Spring	Semi-Annually: Early Spring and Fall
Sampling Depths (inches)	none	0 - 12 & 12 - 24 or refusal	0 - 12 & 12 - 24 & 24 - 36 or refusal	0 - 12 & 12 - 24 or refusal	0 - 12; 12 - 24 & 24 - 36 or refusal	0 - 12; 12 - 24 & 24 - 36 or refusal

1) Common food processing facilities in Idaho include potato (fries and dehydrated products), sugar beet, cheese, and whey processing plants. Potato fresh pack facilities, although not a food processing operation, would be included in this category.

7.4.5 Sampling and Sample Location Determination

7.4.5.1 Sampling

Soil sampling protocols for crop nutrient assessment in soils are discussed in Mahler and Tindall (1990). Sampling protocols are summarized in WLAP permits which require soil monitoring. DEQ (2001) provides soil sampling SOPs (standard operating procedures) in (DEQ 2001) Appendix 'C'. Included are SOPs for the following:

- Collecting representative surface soil samples
- Collecting representative subsurface soil samples with hand augers, split spoon samplers, and from pits and trenches
- Decontaminating soil sampling equipment

Soil sampling should be done when there is sufficient time to complete sampling. Sampling should not be done when soils are excessively wet because compositing is difficult. Soils should not be sampled when snow covered; or have had recent fertilizer, lime, or manure applications (Iowa State University, September 2003; Mahler and Tindall, 1990). In general, several sub-samples from several locations are taken from each sampling interval (see further discussion below) and are composited by depth in a clean plastic bucket to yield a composite sample for chemical or physical analysis. If taking soil cores, the entire core from the particular depth interval should be included as a sub-sample. As described in Mahler and Tindall (1990), soil samples 'need special handling to ensure accurate results and minimize changes in nutrient levels because of biological activity. Keep moist soil samples cool at all times during and after sampling. Samples can be frozen or refrigerated for extended periods of time without adverse effects.' Samples can then be transported to the laboratory in a cooler.

Directions for air drying of soil samples in the following paragraph are paraphrased from A&L Plains Labs, Inc. (no date) unless noted otherwise. Samples can be air dried by spreading the sample in a thin layer on a (clean) plastic sheet. Clods should be broken up and soil spread in a layer about ¼ inch deep. The sample should be dried at room temperature. If a circulating fan is available, position it to move the air over the sample for rapid drying. Do not dry where agricultural chemical or fertilizer fumes or dust will come in contact with the samples. Do not use artificial heat in drying. When soil samples are dry, mix the soil thoroughly, crushing any coarse lumps. Take from the sample about 1 pint (roughly 1 pound) of well-mixed soil and place it in a sample bag or other sturdy, spill-proof container (generally provided by the laboratory) which has sample number, depth, date, time, field number and sampler's name (Mahler and Tindall, 1990). Documentation having sample identification describing the sample and associated information should be written. An example of a soil sample information sheet is in 7.7.6.

7.4.5.2 Sampling Location Determination

Soil monitoring units (SMUs) are specified in wastewater land application permits. SMUs are the predefined areas from which soils are sampled and composite samples are prepared. SMUs are designed so that, in as much as possible, soil properties, cropping practices and wastewater application rates are similar (CES, 1997). Obtaining representative samples is critical to getting valid and interpretable analytical results. Areas should be sampled that are similar in topography, soils, land use and management. Mahler and Tindall (1990), as excerpted and summarized here, recommend that the sampler avoid unusual areas such as eroded sections, dead furrows, fence lines, burn-row areas, wood pile burn areas, gate areas, old building sites, old manure and urine spots, areas of poor drainage, fertilizer bands where row crops have been grown, areas of fertilizer spills, and other unusual areas which would not be representative of SMU soils.

Soil samples should be taken from several different locations in the SMU. Taberna (1992) recommends taking subsamples no closer than 40 feet from the edge of the field. The sampling pattern recommended there is along a transecting loop diagonal (45 degrees) to the field (a diamond shaped transect within a square field). Mahler and Tindall (1990) recommend a zigzag meander pattern to randomly collect samples, being sure to collect samples throughout the unit. Other sampling methods besides a simple random sampling include stratified random sampling, sampling at predetermined locations based upon soil mapping, and using a systematic grid pattern. These are discussed further in CES (1997) and Jacobson (1999).

Special sampling protocols are necessary for furrow irrigated fields, areas where fertilizer has been banded, and on reduced tillage or no tillage fields. These protocols are discussed in Mahler and Tindall (1990)

It is important to note that sampling for nutrient assessment, while adequate for fertility assessment under routine farm management, introduces too much variability for monitoring practices. Soil monitoring should be performed at established locations over time to monitor for changes over time. Valid comparisons over time are not possible if sampling collects from different locations each time. In general, individual locations, grids, or sampling transects should be established to monitor for land application system performance over time.

Table 7-7 gives a recommended number of subsamples to collect based on the size of the field and purpose of sampling:

Table 7-7. Recommended Number of Soil Subsamples.

Field Size in Acres	U of I Recommended Number of Subsamples for Agronomic Nutrient Characterization ¹	DEQ Recommended Number of Subsamples for Regulatory Reconnaissance Characterization
<5	15	5
5-10	18	5
10-15	20	5
15-25	20	10
25-50	25	10
>50	30	10

1) from Mahler and Tindall, 1990

7.4.6 Analytical Methods

Table 7-24 presents analytical methods recommended for soil monitoring. Of particular importance are methods outlined in the Web site:

http://isnap.oregonstate.edu/WCC103/Soil_Methods.htm

This website consists of the on-line version of the Western States Plant, Soil, and Water Analysis Manual, Second Edition, 2003 (hereafter Gavlak et al., 2003).

Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits reported by the laboratory should be significantly less than the ground water standard for constituents that have regulatory limits Quality Assurance and Quality Control

It is recommended that soil testing laboratories utilized for permit required soil analyses are participants in the North American Proficiency Testing Program (NAPT) program for soil, plant and water analyses. The NAPT program is based on the quarterly submission to participating laboratories of six soil and/or three plant materials for chemical analysis using reference methods of analysis described in the four Regional Soil Work Group publications of the Northeast Coordinating Committee on Soil Testing (NEC-67), North Central Regional Soil Testing Committee (NCR-13), Southeast Regional Soil Testing Committee (SERA-6), Nutrient Management and Water Quality Team (WERA-103) and methods outlined in the *Methods Manual for Forest Soil and Plant Analysis*, Forestry Canada.

Participating laboratories complete sample analysis and provide results to the NAPT program coordinator for statistical evaluation. Quarterly, each laboratory will provide an evaluation of their individual performance on each of the methods listed. Annually, the program will provide a report to each participant of the performance of the individual laboratory and that of the agricultural laboratory industry. An extension outreach program to aid participating laboratories in improving the quality of their analytical results will be implemented in cooperation with regional soil and plant analysis work groups and individual state, regional and provincial representatives from the Web site:

<http://www.soiltesting.org/proficiencytesting.html>

The following Web site has information regarding quality assurance in the agricultural laboratory:

<http://isnap.oregonstate.edu/WCC103/Methods/WCC-103-Manual-2003-Lab%20Quality%20Control.PDF>

7.4.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.4.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting soil monitoring data, describe the soil monitoring unit location and use the monitoring serial numbers designated in the permit.

7.4.9 References

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7.5 Wastewater Monitoring

The quality and quantity of the effluent applied to the land treatment area should be monitored on a regular basis. Wastewater sampling and analysis plans are determined based on individual wastewater characteristics, site specific considerations, and regulatory requirements (see Section 2 and Section 7.1.6).

This section provides wastewater monitoring guidance for both municipal and industrial wastewater land application permits and includes wastewater monitoring objectives, instrumentation, monitoring parameters, sampling, analytical methods, quality assurance/quality control and data processing, verification, validation, and reporting.

7.5.1 Monitoring Objectives

The goal of wastewater monitoring at a wastewater-land application facility is to provide a timely and cost-effective assessment of the adequacy of wastewater treatment unit process operations and operation and management procedures. Wastewater chemical and flow monitoring is also critical for constituent loading calculations for permit compliance purposes.

7.5.2 Monitoring Instrumentation

The following section discusses sample collection equipment and flow measurement instrumentation.

7.5.2.1 Sample Collection Equipment

There are various types of wastewater samplers, which are designed to collect sample types described in Section 7.4.4. Refrigerated samplers are designed to take daily composite samples and keep samples at appropriate temperatures for preservation. There are other portable samplers, which can collect hourly composite samples, and can be readily moved to different locations (Metcalf and Eddy, 2003). Some composite samplers can take time-weighted samples, taking identical sample volumes over time. Other samplers can take flow-weighted samples, taking different volumes of sample proportionate to measured flows over time.

7.5.2.2 Flow Measurement

The accurate and precise measurement of wastewater flow is critical for the operation of wastewater land treatment facilities for many reasons. In-plant wastewater treatment processes, which will not be addressed here, rely on flow measurement. Important from a regulatory standpoint is flow measurement to determine both hydraulic loading and constituent loading rates for site management and permit compliance.

Flow measurement is discussed at length in various wastewater engineering texts and the reader is referred there. Important topics to consider regarding flow measurement include:

- Type and application of the flow measurement (metering) device
- Selection criteria for metering devices, and
- Maintenance of metering devices.

Metcalf and Eddy (1991), Tables 6-2, 6-3, and 6-4 provide summary information regarding application, selection criteria, and characteristics of flow metering devices respectively. Flow measurement for industrial facilities is discussed in EPA (1973). Table 7-8, from CLFP (2002), provides a convenient summary of flow measurement devices and advantages and disadvantages.

Table 7-8. Flow Measurement Examples.

Method	Alternatives	Advantages/Disadvantages
Intrusive flow meters	Impeller, paddle wheel Hot wire anemometer	<ul style="list-style-type: none"> - Intrusive devices can clog with solids or from biological growth - higher friction loss/pressure drop - Low pH or high Electrical Conductivity can cause failure of sensing components resulting in higher maintenance
Non-intrusive flow meters	Magnetic Ultrasonic/Doppler	<ul style="list-style-type: none"> + These sensors have no parts in the flow - Higher capital cost + Often, these are used at main pump station and alternate methods are used for individual fields
Open channel flow measurements	Weir-type Parshall flume	<ul style="list-style-type: none"> - Requires controlled channel to establish proper conditions for measurement + Simple, reliable operation + measurements can be recorded continuously
Incoming water supply correlation	Discharge volume is estimated as a percentage of incoming water consumption	<ul style="list-style-type: none"> + Supply water is clean and relatively simple to measure using meters - A correlation between incoming flow, in-plant loss, and process/rinse water discharge is required
Pump run time and output calculation	Flow for individual fields can be estimated proportionally from total flow	<ul style="list-style-type: none"> - Requires a master pump station flow meter or some calibration - Irrigation fields must be maintained so they operate according to specifications - Primarily applicable to sprinkler irrigation systems or surface irrigation using siphon tubes or gated pipe
In-field methods	Rain gauge/catch cans in individual fields Use of soil water measurements to calculate net irrigation	<ul style="list-style-type: none"> + Approximates net irrigation (amounts actually received) rather than gross irrigation delivered - Assumptions in water budget method make method approximate; - calibration required. - Measurement of soil moisture at bottom of root zone provides useful information related to leaching - Rain gauges are applicable to sprinkler irrigation only

From CLFP (2002).

Both wastewater and irrigation water flows need to be measured. Irrigation water generally comes from one source, but can come from multiple sources (well, diverted surface irrigation water). In the latter case, each source should be metered. Irrigation water should be metered at every hydraulic management to measure application rates.

Total wastewater flow to land treatment acreage should be metered from the facility. As with irrigation water, each hydraulic management unit should be metered to measure wastewater application.

Flow data is not compromised by sample contamination, but data verification is important to consider when collecting flow measurements. In some cases flow measurements cannot be safely verified because of the position of the flow measurement device. In other cases the flow measurement device may not be properly constructed, so there is doubt about the measurements produced by the device. For example, a weir may not be level, thus the original engineering calculations used to gauge flow on the weir may not be appropriate for use with the structure as built. Data verification for flow devices should be approached carefully, because in many cases the cost of verification can be great. In some cases documentation showing proper calibration can be presented as a flow verification. All flow

meters should be maintained regularly, according to manufacturer's recommendations, and should be calibrated at least once each year to insure both accurate and precise measurements are being taken.

Further discussion of flow measurement and an in-depth discussion regarding the evaluation of flow measurement devices and records for regulatory purposes is found in EPA (2004), Chapter 6. This chapter is included in this guidance in the supplementary information (Section 7.7.8), and is available at the following Web site:

<http://www.epa.gov/compliance/resources/publications/monitoring/cwa/inspections/npdesinspect/npdesmanual.html>

7.5.3 Monitoring Parameters

This section discusses typical chemical monitoring parameters for wastewater, irrigation water, and operations and unit process monitoring.

7.5.3.1 Chemical Monitoring Parameters

Wastewater chemical analytical parameters to be monitored in wastewater are determined from permit application data, history of the facility wastewater generation, wastewater characteristics of similar facilities and other factors. The permit may require monitoring of constituents in the wastewater for reasons other than to determine compliance with loading or other regulatory limits. Additional parameters to monitor may include toxic chemicals or substances that could upset the treatment system. These substances could be introduced from raw materials, compounds resulting from chemical interactions, or impurities in raw materials including solvents.

Municipal systems typically monitor for total suspended solids (TSS) and biological oxygen demand (BOD₅). These parameters are useful as an indicator of treatment performance prior to land application.

Table 7-9 shows common wastewater monitoring analytical parameters for wastewater land treatment facilities.

Table 7-9. Table of Common Wastewater Monitoring Analytical Parameters for Wastewater Land Treatment Facilities.

Facility Type Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Flow	X ²	X	X	X	X	X
Total Settleable Solids	X	X	X	?	?	?
Total Suspended Solids	X	X	X	?	?	?
Turbidity	X	O	O	O	O	O

pH	X	X	X	X	X	X
Alkalinity	?	?	?	?	?	?
Sodium	O	O	?	?	?	X
NO3-N + NO2-N	X	X	X	X	X	X
TKN	X	X	X	X	X	X
BOD	?	?	?	O	O	O
SO4	O	O	O	?	X	X
Total Dissolved Inorganic Solids¹	O	O	O	?	?	X
VDS	O	O	?	O	?	?
TDS	O	O	X	?	?	?
FDS/NVDS	O	O	?	?	?	?
Electrical Conductivity	O	X	X	X	X	X
COD	O	O	O	?	?	X
P	O	O	X	?	X	X
K	O	O	O	?	X	X
Cl	O	X	X	X	X	X
Total Coliform	X	X	X	?	?	?
Other Micro-organisms	?	?	?	?	?	?

Notes:

1. Total Dissolved Inorganic Solids generally consist of the following ions: Na, K, Ca, Mg, SO₄, Cl, CO₃, HCO₃ and other species in appreciable concentration.
2. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

Irrigation water quality is often measured at wastewater land treatment facilities, where there is need to account for constituent loading from this source. In cases where irrigation water does not vary appreciably during the water year, nor between water years, sampling and analysis during the spring and fall of the first water year of the permit cycle is usually considered sufficient. For cases where there is more variability, additional monitoring may be necessary for chemical characterization. Typical constituents of concern are salts (as measured by TDS analysis) and total nitrogen (as measured by TKN plus nitrate-nitrogen analyses). Chloride may be necessary for sites where ground water modeling is being, or may be, conducted. Chloride is a conservative constituent (i.e. does not undergo chemical transformations in an agronomic soil environment) and can be used for modeling calibration purposes.

7.5.3.2 Operations and Unit Process Monitoring

Operations monitoring is an important component of the wastewater monitoring program. Operations monitoring includes monitoring performance of irrigation systems including inspection and cleaning of sprinklers. Observation during both growing and non-growing season during wastewater irrigation for runoff, ponding, vectors, ice build-up and other irregularities is important. Precipitation and evapotranspiration should also be monitored.

Cumulative constituent and hydraulic loadings onto hydraulic management units should be monitored throughout the application season so that sound wastewater land treatment management decisions can be made.

Lagoon water levels need to be monitored. Lagoon berms need to be inspected regularly for rodent damage and for weed control. Operation of pumps, clarifiers, screens, filter presses, centrifuges and other unit processes must be closely monitored. Ground water mounding around lagoons should also be monitored using piezometers.

Table 7-10, adapted from CLFP (2002), summarizes operations monitoring in a checklist for routine maintenance for use at a wastewater land treatment facility.

Table 7-10. Routine Maintenance Inspection Checklist for Land Application Sites Monitoring.

Feature	Condition	Recommended Action
Facility Discharge	Check primary screens for solids accumulation, amount of flow, evidence of unusual conditions	
Lagoon or Pond	Pond level, odor, scum on surface, presence of excessive solids, berm inspection for rodent damage and weed control	
Residuals Stockpile	Amount, need for land application, odor	
Main Pump Station	Current operations, flow, pressure, odor, leaks, mechanical concerns	
Transmission Piping	Leaks, odor, pressure at intermediate locations	
Booster Pumps	Current operations, flow pressure, odor, leaks, mechanical concerns	
Other Unit Processes	Monitoring of clarifier, filter presses, centrifuges, etc.	
Fields irrigated	For each field: list irrigation run times, process water or supplemental water supply, odor	
Constituent Loading	Cumulative constituent and hydraulic loadings throughout growing and non-growing seasons	

Feature	Condition	Recommended Action
Fields condition	For each field: assess irrigation uniformity, runoff, erosion, irrigation system condition, odor, solids on surface, ice buildup, ponding, vectors,	
Crop Condition	For each field: general crop health, need for farming activities	
Samples Collected	List samples taken	

Adapted from CLFP (2002).

7.5.4 Monitoring Frequency

Wastewater monitoring frequency is determined based on the measured or estimated variability (see Section 7.1.3). Other factors for determining sampling frequency include the following:

- Size and design capacity of facility
- Type of treatment
- Compliance history
- Number of pollutant sources from a facility
- Cost of monitoring relative to the facility's capability and benefits obtained
- Environmental significance of wastewater constituents
- Detection limits and analytical precision/accuracy
- Production schedule of the facility (seasonal, daily, year round, etc.)
- Plant washdown or cleanup schedule
- Batch type process and discharge or continuous operation

The number of samples necessary to determine compliance for total coliform is related to the degree of public exposure, as rated by total coliform counts in wastewater (see Table 7-11). The WLAP rule (IDAPA 58.01.17.600.07) specifies the use of the median sample value for the last three to seven test results to determine compliance, depending on the effluent classification.

Table 7-11. Total Coliform Testing Frequency and Compliance Determination for Municipal Systems

Wastewater Category	Median Coliform Limit	Single Sample Maximum Value**	Recommended Sampling Frequency	Compliance Determination Method
Class A	Filtered, Total Coliform limit: 2.2/100 ml *	23/100 ml	Daily when land application system is in operation, or project specific	O&M manual must include provisions to divert effluent or shut down application system whenever bacterial excursions occur or may occur; Median value of last 7 results, rolling basis
Class B	Total Coliform limit: 2.2/100 ml	23/100 ml	Twice per week when land application system is in operation	Median value of last 7 results, rolling basis
Class C	Total Coliform limit: 23/100 ml	240/100 ml	Weekly when land application system is in operation	Median value of last 5 results, rolling basis
Class D	Total Coliform limit: 230/100 ml	2400/100 ml	Twice per month when land application system is in operation	Median value of last 3 results, rolling basis
Class D	Too Numerous to Count – Not Applicable	Not Applicable	Twice per month when land application system is in operation	Not Applicable

Notes:

* This category requires filtration performance standards (turbidity or TSS) prior to disinfection.

** The facility shall include provisions to divert effluent or shut down application system whenever bacterial excursions occur or may occur

Municipal wastewater land application permits should include a total coliform maximum limit, in addition to the median limit. For compliance, using the median value allows a certain number of individual samples to have unlimited bacteria counts. Including a single sample maximum value provides needed public health protection, and requires facilities to monitor their disinfection systems more closely. See Table 7-11 for suggested maximum limits according to wastewater category.

Municipal permits typically have hydraulic loading rates be calculated on a monthly basis. If a system is having problems managing the site properly, a weekly basis may be more appropriate.

Frequency of wastewater constituent monitoring for industrial wastewater land application facilities is summarized in Table 7-27. Frequency of wastewater constituent monitoring for municipal wastewater land application facilities is summarized in Table 7-28.

7.5.5 Sampling and Sample Location Determination

7.5.5.1 Sampling

Detailed information for developing a wastewater sampling program is found in Section 7.1.6 in the context of development of the quality assurance project plan (QAPP). The publication, *Monitoring Industrial Wastewater*, EPA, 1973, can also be consulted. The

information is also applicable to municipal wastewaters. There are several types of wastewater samples that can be collected: *grab*, *composite*, and *continuous sampling*, all of which are discussed in the following.

The wastewater sample type will depend on several factors:

- The parameter to be monitored.
- The temporal and spatial variability of the wastewater sampled; and
- The type of limit. Limits based on instantaneous or one hour values may be sampled using grab sampling techniques. Limits based on average values or daily maximums may be sampled using time or flow proportional composite samples. This is acceptable for certain conventional pollutants, nutrients, and bio-accumulative pollutants, for which percent removal and total loading to the receiving water are of concern.

7.5.5.1.1 Discrete Grab or Sequential Grab Samples

A wastewater grab sample is an individual sample collected in less than 15 minutes time. It represents more or less "instantaneous" conditions as discussed in Section 7.1.4. Grab samples should be used when:

- Wastewater characteristics are relatively constant.
- The parameters to be analyzed are likely to change with storage such as temperature, dissolved gasses, residual chlorine, soluble sulfide, cyanides, phenols, microbiological parameters and pH.
- The parameters to be analyzed are likely to be affected by the compositing process such as oil, grease, and volatile organic compounds.
- Information on variability over a short time period is desired.
- Composite sampling is impractical or the compositing process is liable to introduce artifacts of sampling.
- The spatial parameter variability is to be determined. For example, variability through the cross section and/or depth of a stream, lagoon or other large body of water.
- Wastewater flows are intermittent from well-mixed batch process tanks. Each batch dumping event should be sampled.

Another type of grab sample is sequential sampling. A special type of automatic sampling device collects relatively small amounts of a sampled stream, with the interval between sampling either time or flow proportioned. Unlike the automatic composite sampler, the sequential sampling device automatically retrieves a sample and holds it in a bottle separate from other automatically retrieved samples. Many individual samples can be stored separately in the unit, unlike the composite sampler, which combines aliquots in a common bottle. This type of sampling is effective for determining variations in media characteristics over short periods.

7.5.5.1.2 Composite Samples

As discussed in Section 7.1.4, a composite sample consists of a series of individual samples collected over time into a single container, and analyzed as one sample. Composite sampling is employed when time or flow-weighted constituent concentration averages are needed (see below), or when mass per unit time information is needed. There are two general types of composite samples.

- **Time composite samples** collect a fixed volume at equal time intervals and are acceptable when flow variability is not excessive. Automatically timed composited samples are usually preferred over manually collected composites. Composite samples collected by hand are appropriate for infrequent analyses and screening. Composite samples can be collected manually if subsamples have a fixed volume at equal time intervals when flow variability is not excessive.
- **Flow-proportional compositing** is usually preferred when Wastewater flow volume varies appreciably over time. The equipment and instrumentation for flow-proportional compositing have more downtime due to maintenance problems. When manually compositing Wastewater samples according to flow where no flow measuring device exists, use the influent flow measurement without any correction for time lag. The error in the influent and wastewater flow measurement is insignificant except in those cases where extremely large volumes of water are impounded, as in reservoirs. Use composite samples when either determining average concentrations, or calculating mass loading/unit of time.

There are numerous cases where composites are inappropriate. Samples for some parameters such as pH, residual chlorine, temperature, cyanides, volatile organic compounds, microbiological tests, oil and grease, and total phenols should not be composited. They are also not recommended for sampling batch or intermittent processes. Grab samples are needed in these cases to determine fluctuations in wastewater quality.

The compositing time period and frequency of aliquot collection should be determined. Whether collected by hand or by an automatic device, the time frame within which the sample is collected should be specified in the permit. The number of individual aliquots which compose the composite should also be specified. A minimum of four aliquots during a 24-hour period is common for wastewater composite samples.

7.5.5.1.3 Continuous Monitoring

Continuous monitoring is another option for a limited number of parameters such as total organic carbon (TOC), temperature, pH, conductivity, fluoride and dissolved oxygen. Reliability, accuracy and cost vary with the parameter. Continuous monitoring can be expensive, and has limited applicability to wastewater land treatment facilities. The environmental significance of the variation of any of these parameters in the wastewater should be compared to the cost of continuous monitoring equipment available.

Process control monitoring has been generally discussed both in Section 7.1.1 and Section 7.4.3.2. It refers to monitoring of internal waste streams in order to verify that proper waste treatment or control practices are being maintained. The wastewater treatment process will determine the types of process control monitoring needed.

Additional sampling information is given in the *Handbook for Sampling and Sample Preservation of Water and Wastewater*, EPA (1982).

7.5.5.2 Sampling Location Determination

Permanent sampling locations should be determined and identified in permit application materials. The permit applicant should provide a description of the wastewater sampling station location and in most cases, a line drawing and description of the flows and processes involved in wastewater treatment.

The point at which a sample is collected can make a large difference in the monitoring results. Important factors to consider in selecting the sampling station are:

- The flow at the sampling station should be measurable.
- The sample should be representative of the wastewater during the time period which is monitored.
- If possible, the sample should be collected where the wastewater is well-mixed. Therefore, the sample should be collected near the center of the flow channel, at a depth of approximately half the total depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Acceptable sampling locations can include near a Parshall flume or at a location in a sewer with hydraulic turbulence. Weirs tend to enhance the settling of solids immediately upstream and the accumulation of floating oil or grease immediately downstream. Such locations should be avoided for sampling.
- Skimming the water surface or dragging the bottom should be avoided.
- In sampling from a mixing zone, cross-sectional sampling should be considered. Dye may be used as an aid in determining the most representative sampling points.
- If manual compositing is employed, the individual sample bottles must be thoroughly mixed before pouring the individual aliquots into the composite container.

It is often convenient to combine a flow measurement station with a sampling station. When flumes are used for flow measurement, the sample is usually well mixed. Wastewater samples should be collected at a location which represents wastewater quality which is to be land applied. More than one wastewater sampling station may be necessary for two separate wastewater streams which are not mixed, but are land applied separately.

7.5.6 Analytical Methods

Table 7-29 presents analytical methods which are recommended for wastewater monitoring. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. As discussed in Section 7.1.5, practical quantitation limits (PQLs) reported by the laboratory should be appropriate for constituents which have regulatory limits.

For chlorine residual “free” chlorine should be specified. Metcalf & Eddy (1991) states “the main reason for adding enough chlorine to obtain a free chlorine residual is that usually disinfection can then be ensured.” Chlorine residual monitoring and monthly reporting should be required in permits.

7.5.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.5.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the system’s permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting wastewater monitoring data, describe the sampling location and use the monitoring serial numbers designated in the permit.

Municipal permits should generally require monthly reports for hydraulic loading rates, chlorine residual, and total coliform. The need for this should be determined by the regional office. If monthly reports are necessary to maintain adequate system oversight, it can be specified in the permit.

7.5.9 References

- CLFP. California League of Food Processors. September 20, 2002. Final Report: Manual of Good Practice for Land Application of Food Process/Rinse Water for California League of Food Processors. Brown and Caldwell, Kennedy Jenks, Komex H₂O Science.
- EPA. U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-CI111), EPA-600/4-79-020. Revised March 1983 and 1979 where applicable.
- EPA. U.S. Environmental Protection Agency. 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA-600/4-82-029.
- EPA. U.S. Environmental Protection Agency. July 2004. NPDES Compliance Inspection Manual. Office of Enforcement and Compliance Assurance, Washington D.C.
- Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.
- Bordner, R.H., and J.A. Winter, eds. 1978. "Microbiological Methods for Monitoring the Environment, Water and Waste." Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency. EPA-600/8-78-017.
- Association of Official Analytical Chemists, Official Methods of Analysis (AOAC). 1990 15th Edition.
- Metcalf and Eddy (Eds. Tchobanoglous, G., and F. L. Burton). 1991. Wastewater Engineering – Treatment, Disposal, and Reuse. Metcalf and Eddy Inc. 3rd Edition. McGrawHill, Inc. 1334 pages.

Metcalf and Eddy (Revised by Tchobanoglous, G., F. L. Burton, and H.D. Stensel). 2003. Wastewater Engineering – Treatment, Disposal, and Reuse. Metcalf and Eddy Inc. 4th Edition. McGrawHill, Inc. 1819 pages.

7.6 Crop Monitoring and Yield Estimation

7.6.1 Monitoring Objectives

Crop monitoring includes maintaining chronology of cropping activities, plant tissue monitoring, and crop yield estimation. Cropping activity chronology would include dates of planting, harvest, tillage operations, fertilizer application, and dates where crop health was observed (CLFP, 2002 p. 10-18). Crop yield estimation is important to calculate crop uptake of nutrients and salts for regulatory compliance purposes.

Plant tissue monitoring is generally used to ascertain the nutrient status of a growing crop for managing fertilizer applications for maximizing crop yield and quality – i.e. for nutrient sufficiency and deficiency determination. Plant tissue monitoring is also conducted to determine feed value, nutrient toxicity and, in certain instances, the presence and concentration of toxic compounds, of a harvested crop.

The purpose of plant tissue monitoring as it pertains to permitted wastewater land treatment facilities is to determine crop uptake of nutrients and other constituents, and their removal from the treatment acreage. Crop uptake monitoring is discussed primarily in this section. Crop uptake monitoring data are used in nutrient and other constituent balance calculations in order to help characterize constituent losses to the environment. For example, if it is known how much nitrogen is in the soil in early spring, the amount of nitrogen applied in wastewater and fertilizers, how much is in the soil after harvest, and how much is taken up and removed by the crop, the difference represents losses of the constituent to the environment. Such loss estimates can then be partitioned into various pathways of loss, such as leaching and atmospheric losses. Estimates of leaching losses can then be used in conjunction with site-specific environmental data and modeling to help characterize the potential and degree of environmental impacts, such as those to ground water.

7.6.2 Monitoring Instrumentation

See Section 7.6.5.1 for description of sampling equipment used for plant tissue monitoring.

7.6.3 Monitoring Parameters

Parameters of interest for plant tissue monitoring at wastewater land application facilities include nitrogen, phosphorus, and some measure of inorganic salts.

7.6.3.1 Nitrogen

Nitrogen in plant tissue is typically measured from TKN analyses. TKN measures reduced forms of nitrogen in plant tissue including proteins and nitrogen in cellular tissues. The

TKN analyses does not measure nitrate in plant tissue, so nitrate should be analyzed as well.

Nitrate concentrations in plant tissue can be significant in crops which have been grown with an abundance of supplied nitrogen. The presence of elevated nitrate levels in plant tissue can indicate that luxury consumption – crop uptake above the amount of nutrient a crop would normally need to take up to satisfy growth and development demands – has likely occurred.

Alternately, elevated nitrate levels in plant tissue can indicate nutrient stress; moisture stress; or cloudy, cool weather that can cause slow metabolism of nitrate to ammonia in the synthesis of amino acids in the plant (reference).

Nitrate is also important to characterize because it can be toxic to animals. Lethal dose is determined by the nutritional state, size, and type of animal; and consumption of feed other than nitrate-containing material:

- Ruminant animals are most sensitive to nitrate intake, because nitrate is converted to nitrite in the rumen and nitrite binds and inactivates hemoglobin in the bloodstream.
- Concentrations of less than 1,000 mg/kg in the feed ration are acceptable for all cattle.
- Concentrations greater than 2,000 are not suitable for the entire feed ration and should be blended with other feed.
- Potentially lethal level of nitrate-nitrogen in animal feed is over 2,100 mg/Kg (Ensminger et al., 1990).

Nitrate in plant tissue can be chemically reduced to benign forms by green-chopping and ensiling and crop. This is a common practice at many wastewater land treatment facilities, not only for the removal of nitrate, but to achieve rapid removal of the harvested crop so that wastewater land treatment activities can proceed with only minimal delays.

7.6.3.2 Phosphorus

Phosphorus is also important to assess in plant tissue. A significant amount of phosphorus can be taken up by the crop and removed at harvest. Accounting for these amounts is important when determining permit limits for phosphorus loading to land application sites.

7.6.3.3 Salts

Inorganic salts are important to assess in plant tissue. Accounting for inorganic salt uptake in crops can be significant when modeling salt (i.e. TDS) impacts to ground water. The ash content of plant tissue is assumed to represent these salts. A significant amount of inorganics are taken up by the crop and removed at harvest.

7.6.4 Monitoring Frequency

Plant tissue monitoring for obtaining data for nutrient and other constituent balances is done at harvest. For hay crops, each cutting is a harvest, so samples should be obtained from each

cutting and each hydraulic management unit. For crops that are harvested once at the end of their respective growing seasons, sampling should take place then.

7.6.5 Sampling and Sample Location Determination

7.6.5.1 Sampling

Only the plant parts that are removed from the site need be sampled. In the case of a hay crop, the entire plant top is cut and removed, so the entire plant should be sampled. In the case of small grains, if the grain and stover (above-ground plant parts excluding the seed) are both harvested and removed, both should be sampled. If the stover is left on site, then only the grain should be sampled.

CES (1997) outlines plant tissue sampling methods, which are summarized here. Plant tissue samples of green, growing crops such as forages should be taken immediately prior to harvest. Sampling forage crops immediately prior to harvest can result in 10 to 20 percent higher nitrogen levels because of plant tissue degradation following harvest. Samples should be collected to be representative of the crop at the time of harvest or just prior to harvest. Sampling of small areas of the field where plants are under severe moisture or temperature stress is not recommended. Plants that are dust covered, mechanically injured, diseased, or dead should not be sampled (Walsh and Beaton, 1973). The exception to this is when mechanical injury, disease or crop death is representative of the material being harvested. Crop tissue should be tested in these cases.

Samples should be collected at random locations in the hydraulic management unit. Specific crop types require particular sampling methods. For harvested grain, bean, silage or green chop, one grab sample from each day of harvest should be collected. They should be placed in paper bag and refrigerate, then mixed and a composite sample (1 liter wet or ½ liter dry) sent to the laboratory. For bailed hay, collect three composite samples from each harvest from each field. Each hay sample should be composited from at least ten cores from the ends of randomly selected bales. Then mix and send to the laboratory.

Potatoes require special sampling methods due to their size and the presence of two harvested plant parts, namely the potato and the vines. Collect one grab sample per day during harvest consisting of at least five potatoes. Quarter each potato and discard three of the quarters. Retain one quarter from each potato for a daily grab sample. Keep subsamples refrigerated and send all quarters to the laboratory for analysis. If the potato vines are to be burned, vine yield and nutrient (nitrogen only) uptake by the vines should be measured. Collect the vines from three four-foot sections of row in four locations in each hydraulic management unit (CES, 1997). Then reduce the sample size by splitting the pile of collected vines prior to shipping to the laboratory. Refrigerate after sampling and send at least 1 liter, but preferably one gallon, of volume of sample to the laboratory.

For forage crops, each sample should consist of the clippings from a minimum ten square feet of area. A square wooden frame or a wire whoop placed on the forage is effective to delineate the area to be sampled. The frame should be randomly dropped along a transect or grid pattern. The plants should be clipped within the frame at the same level that would result from the mechanical harvesting equipment. Hand operated or other clippers may be used. Place each composite sample in a large paper bag so the sample can 'breathe' (some

sources recommend a perforated plastic bag). Put the sample in a cool place and deliver to the laboratory within two hours (CES, 1997). Ship or store samples in a chilled cooler if delivery in two hours cannot be accomplished. Delivery within 24 to 48 hours is acceptable if samples are kept dry and chilled in 'breathable bags. Illinois (no date) recommends a quick washing of plant tissue in a 0.1 – 0.3 percent non-phosphate containing detergent accompanied by three rinses in de-ionized water, in order to remove any dust, fertilizer, pesticide or other residues from the leaf surfaces.

As an alternative to collecting and transporting fresh plant tissue samples to the laboratory within short time-frames, samples may be dried in a clean muslin bag or tray inside a forced draft oven at 65 C for 48 hours. Tissue samples may then be ground after drying and placed in a bottle and allowed to dry for an additional 24 hours at 65 C. After this, samples are ready for analyses (Illinois, no date). Walsh and Beaton (1973) may be consulted for further information regarding plant tissue sampling and analyses.

7.6.5.2 Sampling Location Determination

As mentioned in 7.6.4, each harvest of every crop on a hydraulic management unit should be sampled. Sampling within the hydraulic management unit is addressed in 7.6.5.1.

7.6.6 Analytical Methods

Table 7-12 presents analytical methods that are recommended for plant tissue sample analysis.

Table 7-12. Plant Tissue Analyses.

Parameter	Abbreviations	Units	Recommended Methods(1)
Crude Protein	--	% by weight	TKN * factor(2)
Total Kjeldahl Nitrogen	TKN	% by weight	978.04
Total Combustible Nitrogen	TCN	% by weight	990.03 Note: This method yields results comparable to TKN above and is becoming more commonly used.
Nitrate + Nitrite	NO3 + NO2	% by weight	968.07
Ash	--	% by weight	930.04
Moisture	--	% by weight	930.05

1. Association of Official Analytical Chemists, Official Methods of Analysis (AOAC). 1990 15th Edition. All methods cited in this appendix are recommended methods. Other comparable methods yielding the same interpretive results are acceptable unless otherwise stated in the Land Application of Wastewater Permit.

2. Use 6.25 for mixed feeds and forages; 5.72 for grains.

7.6.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.6.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting plant tissue

monitoring data, describe the sampling location (hydraulic management unit) and use the monitoring serial numbers designated in the permit.

7.6.9 Crop Nutrient Content Reference Values

Wastewater land treatment sites that are loaded at agronomic rates or up to 150% of the agronomic rate are often required to have crop chemical analyses performed and make crop nutrient removal calculations. It may be appropriate for certain sites loaded at or below agronomic rates to use crop nutrient concentration values found in standard tables. Table 7-30 compiles nitrogen contents of a wide variety of crops. Sources of the data are documented in the footnotes. Ducnuigeen et al. (1997), Tables B-1, B-2, and B-3 provide a comprehensive source of non-crop species nitrogen and phosphorus uptake information. These tables are found at the following Web site:

http://www.potomacriver.org/info_center/publicationspdf/ICPRB97-4.pdf.

Table A-2 of Martin et al. (1976) provides typical ash, nitrogen, phosphorus, and moisture content information for cereal crops. Table A-1 of Martin et al. (1976) gives weight per bushel information for cereal crops. These two tables are included in Appendix Y below. The USDA NRCS web site

<http://www.nrcs.usda.gov/technical/land/pubs/nlapp1a.html>

also provides nitrogen, phosphorus and potassium uptake rates. Bushel weights of common commodities are also found in Table 31 of Midwest Laboratories (no date).

Typical yields for common Idaho crops by county and by year can be obtained from the Idaho Department of Agriculture, Agricultural Statistics Division. A useful Web site is the following:

http://www.nass.usda.gov:81/ipedbcnty/c_groupcrops.htm

7.6.10 Crop Yield Estimation

CES (1997) provides guidance on how to estimate crop yields from wastewater land treatment sites. This guidance is summarized here. The date of harvest should be recorded, as should the harvest method (bale, green chop, other) and crop type. The crop yield from each harvest, such as multiple cuttings, should be recorded. For forage crops, either the total measured weight method or average bale weight methods can be used, as discussed below. Both methods require the measurement of moisture content of the harvested material to calculate dry weight.

7.6.10.1 Total Measured Weight Method

The total measured weight method requires each truckload of harvested material to be weighed. This method is best suited to crops that are immediately removed from the field, including corn grain, corn silage small grains, potatoes, and green chopped hay.

The methodology is as follows:

1. Measure each full truckload weight and empty truckload weight. The difference is the individual truckload weight of harvested material.
12. Sum all individual truckload weights to obtain total harvested weight.
13. Calculate the total dry matter weight as follows:
$$\text{Total harvested weight (lbs)} * (1 - \text{moisture content expressed as a fraction}) = \text{total dry matter content (lbs)}$$
14. Convert total dry matter to average yield as follows:
$$\text{Total dry matter content (lbs)} \text{ divided by field size (acres)} = \text{average yield (lb/acre)}$$

7.6.10.2 Average Bale Weight Method

The average bale weight method is best suited for forage crops or other crops removed in uniform discrete units. This method involves weighing at least 20 randomly chosen bales or one truck load of at least 20 randomly chosen bales. The average weight per bale of these bales is then calculated from individual bale weights. The total harvest weight consists of counting the number of bales from a field and multiplying by the average weight per bale. The total harvest weight of the field is converted to total dry matter weight and average yield in the manner described in nos. 3) and 4) above.

7.6.11 References

- Cascade Earth Sciences, October 1997. Process Water Irrigation Systems: Design and Management. Soil and Crop Monitoring.
- CLFP. California League of Food Processors. September 20, 2002. Final Report: Manual of Good Practice for Land Application of Food Process/Rinse Water for California League of Food Processors. Brown and Caldwell, Kennedy Jenks, Komex H₂O Science.
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- Ducnuigee, J., K. Williard, and R.C. Steiner. September 1997. Relative Nutrient Requirements of Plants Suitable for Riparian Vegetated Buffer Strips. Interstate Commission on the Potomac River Basin. ICPRB Report Number 97 – 4.
- Ensminger, M.E., J.E. Oldfield, and W.W. Heinemann. 1990. Feeds and Nutrition Digest. Second Edition. The Ensminger Publishing Company, Clovis, California. Page 103.
- Follett, R.F., Keeney, D.R., and Crose, R.M., 1991. Managing Nitrogen for Ground Water Quality and Farm Profitability.
- Illinois, State of. No date. Administrative Code, Title 35: Environmental Protection; Chapter II: Environmental Protection Agency; Part 391: Design Criteria for Sludge Application on Land; Section 391.530: Plant Tissue Sampling and Analyses.
- Martin, J., W.H. Leonard, and D.L. Stamp. 1976. Principles of Field Crop Production – Third Edition. Macmillan Publishing Company, Inc. 1118 pp.
- Midwest Laboratories. No date. Agronomy Handbook. 132 pp.
- Walsh, L.W., and J.D. Beaton (eds), 1973. Soil Testing and Plant Analysis, Revised Edition. Soil Science Society of America, Inc.

7.7 Supplemental Information

7.7.1 General Discussion Supplemental Information

The following supplemental information provides additional information on determining sample size and a recommended QA/QC Plan outline.

7.7.1.1 Statistical Methodology for Determining Sampling Frequency

The following is a method to calculate the sample size (related to sample frequency) required to meet specified accuracy and confidence levels when characterizing the chemistry of wastewater. This methodology is incorporated into the wastewater sampling frequency spreadsheet, *WW_Sampling_Frequency_Tool.xls*. This methodology may be used for determining sampling frequencies of other sampled media as well.

In the spreadsheet, wastewater chemical oxygen demand (COD) concentration from a potato processing WLAP site is used as example data. The true mean is usually unknown, so it is estimated by a flow-weighted average, using:

$$\hat{\mu} = \frac{\sum_{i=1}^m Q_i C_i}{\sum_{i=1}^m Q_i}$$

Equation 7-1 Estimating mean using a flow-weighted average.

Where:

$\hat{\mu}$ = estimated mean or flow weighted average

Q_i = the flow rate in the i^{th} time interval

C_i = the i^{th} constituent concentration

m = the total number of observations

In the *WW_Sampling_Frequency_Tool.xls* spreadsheet, the time interval is one day, therefore $i = 1, 2, \dots, 366$. The weighted average of COD concentration (mg/l) is shown in cell C372 of the Data Input worksheet. Sum (Q_i), the total flow rate (MG), is shown in cell B371 of the *Data Input* worksheet.

Sample size, n , is calculated based on:

$$n = \frac{z_{\alpha/2}^2 s^2}{B^2}$$

Equation 7-2. Calculating sample size.

Where:

- n = sample size required. On the *Stat Output* worksheet of the *WW_Sampling_Frequency_Tool.xls*, the required n is rounded to the next larger integer value of the calculated n .
- $z_{\alpha/2}$ = the $(\alpha/2)^{\text{th}}$ percentile of the standard normal distribution
- α = the significance level, the confidence level is $(1-\alpha)100\%$. Conventionally, α is specified at 0.05, which gives 95% confidence interval of the estimated parameter. Other confidence levels may be more appropriate depending upon the medium, parameter, and purpose of the data.
- s = standard deviation of the sample
- B = maximum allowable error in the estimation of the mean and is denoted either by percentile of the mean or as an absolute value.

The *Stat Output* worksheet provides several maximum errors, in estimating the mean (B) and confidence levels, to choose from, and their corresponding sampling frequency requirements (n). An example of the spreadsheet output is shown in Figure 7-4.

Sample Frequency Statistical Output Calculations								
Sample size (n) based on different levels of accuracy and confidence error allowable (B) is taken as percentage of the mean.								
following is based on COD, note that final n should be rounded to the next large integer								
B (% mean)	B	Upper	Lower	confidence level				
				80%	85%	90%	95%	99%
5	144	3028	2739	99	126	164	233	401
10	288	3172	2595	25	32	41	59	101
15	433	3316	2451	11	14	19	26	45
20	577	3460	2307	7	8	11	15	26
25	721	3604	2163	4	6	7	10	17
30	865	3749	2019	3	4	5	7	12
Notes: 1) 'B' is the maximum error about the mean one is willing to accept, as expressed as a percent of the mean concentration or as expressed as a number (column B). 2) The upper and lower bounds from the mean with a given 'B' are shown in columns C and D. 3) Need >20 data points; assume normality of data. Use data from several years if necessary to obtain 20 data points.								

Figure 7-4. Example of Statistical Output of the Spreadsheet: *WW_Sampling_Frequency_Tool.xls*

7.7.2 Recommended Contents for a Facility Quality Assurance/Quality Control Plan

Revision 1

12/12/05

Template for Quality Assurance Project Plan

Prepared: March 30, 2001

EPA Documents Relevant to Preparation of a Quality Assurance Project Plan

EPA Order 5360.1 CHG 1, Policy and Program Requirements for the Mandatory Agency-Wide Quality System requires that guidelines in ANSI/ASQC E4-1994 AMERICAN NATIONAL STANDARD Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs, and EPA QA/R-5, EPA Requirements for Quality Assurance Project Plans be used in describing a quality management system.

Revision 1

12/12/05

1.1 Title and Approval Page

Project Title

Organization
Address
Town, State

Revision: 0
Date:

Applicant Approval:

Approval Signature:
Phone:

IDEQ Acceptance and Approval:

Organization Title: Idaho Department of Environmental Quality

Address: 1410 North Hilton St. Boise, ID 83706

IDEQ Approval:

Approval Signature:
Phone:

Revision 1

12/12/05

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Revision 1

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2.7 Instrument Calibration and Frequency

2.8 Inspection/Acceptance Requirements for Supplies and Consumables

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7.7.3 Ground Water Monitoring Supplemental Information

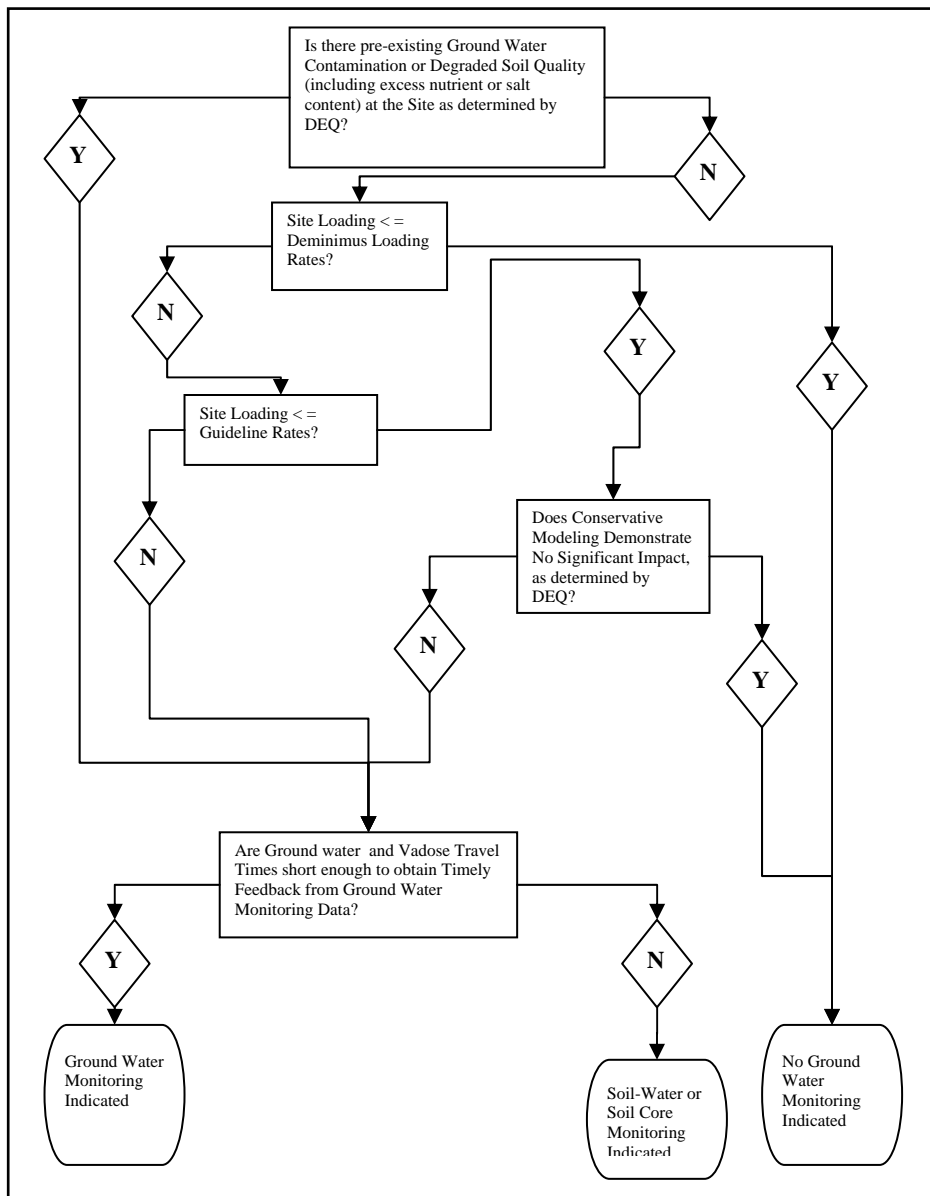


Figure 7-5. Decision Flowchart to Determine Whether Ground Water Monitoring is Needed at a Wastewater Land Application Site

7.7.3.1 Monitoring Well Construction

Details regarding the construction of monitoring wells are found here. Included in this appendix are discussions of drilling methods; selection of screened interval depths; casing materials; seals, packing and grouting; and monitoring well development.

7.7.3.1.1 Drilling Methods

There is a variety of different types of drilling methods. Care should be taken to minimize the introduction of contaminants into the borehole during drilling since this may compromise the analytical results of the ground water quality samples collected from this well. Table 7-13, summarizes the most common drilling methods.

Table 7-13. Drilling Methods.

Method	Environment	Advantages	Disadvantages
Hollow-stem continuous flight auger	Glaciated or unconsolidated materials (< 150 ft)	mobile fast inexpensive no drilling fluids minimal disturbance to formation	cannot be used in loose large cobbles drilling depth 150 ft
Cable tool	Glaciated or unconsolidated materials (any depth), Consolidated formations (any depth), excellent for glacial till, effective in boulder Environments	excellent for formation sample collection minimal water used easy detection of water table driven casing seals well, preventing cross contamination	relatively slow minimum size diameter limited to 6 inches difficult to collect rock samples
Air rotary (with foam)	Consolidated or unconsolidated formations, no depth limitations	quick and efficient core samples easily collected	introduction of air to ground water may alter chemistry foam may interfere with organic and inorganic parameters (1) loss of circulation in fractured or high permeability zones potential to miss saturated zone
Bucket auger	Fine grained formations, Shallow (< 100 ft), large diameter wells, difficult in boulder environment	less well development is required less potential for cross contamination	disturbs large areas of the formation
Solid-stem continuous flight auger (generally not recommended)	Glaciated or unconsolidated materials (< 150 ft)		limited to unconsolidated fine grained materials drilling depth 150 ft. difficult to collect formation samples

Method	Environment	Advantages	Disadvantages
Reverse circulation rotary (generally not recommended)	Consolidated formations	formation sampling	limited applications uses large quantities of water
Mud rotary (generally not recommended)	Consolidated formations to any depth	fast drilling flowing artesian conditions can be managed.	mud and water circulated through borehole difficult to completely remove all mud mud may contain organic matter high potential for cross contamination may alter ground water chemistry may alter permeability

Notes:

- (1) The effects of air injection would not be long-lived if the well is developed properly. Foams approved for potable water wells by the National Sanitation Foundation would not be problematic if used according to specifications.
- (2) Not listed in order of preference.

7.7.3.1.2 Screened Interval

The depth and the length of the screen interval of a well should ensure that the samples will be obtained from the portion of the aquifer that will detect the earliest impacts of wastewater land treatment on ground water quality. For the majority of sites, this will be the uppermost portion of the uppermost aquifer.

This element of well construction is site specific, depending upon the contaminants of concern (typically nitrate, total dissolved solids (TDS), iron, manganese, and chloride) and the characteristics of the aquifer. Contaminants may be confined to narrow zones within an aquifer. Table 7-14 describes the advantages and disadvantages of both short and long well screens. In situations where it may not be sufficient to monitor all contaminants with a single well, multiple wells, or well clusters may be installed.

Table 7-14. Advantages and Disadvantages of Short and Long Well Screens.

Well Screen Type	Advantages (+) and Disadvantages (-)
Short well screens (2-5 feet)	<ul style="list-style-type: none"> + Allow discrete sampling of the formation. targeting contaminants concentrated at specific depths. + Isolate a single flow zone. - Does not allow for substantial vertical dilution in the borehole. + Easier to detect increases in contaminant concentrations. - Not appropriate for long-term monitoring in aquifers with declining water levels.
Long well screens (10-20 feet)	<ul style="list-style-type: none"> + Ideal for aquifers whose potentiometric surface fluctuates dramatically. + Allow sufficient quantities of water to enter the borehole in low-permeability aquifers.

Multiple wells installed with well screens at various depths are appropriate when the aquifer is heterogeneous, when the site geology is complex, when there are fractures or faults present, when multiple aquifers will be affected, when there is a perched aquifer, or when the aquifer is discontinuous, (EPA, 1986).

In areas with extreme water table fluctuations, more than one monitoring well may be needed, so that the water table can be adequately sampled. For example, in paired wells, the upper and lower screens should be 10 to 15 feet in length for the shallow and deep well respectively. The bottom of the upper screen of the shallow well should end where the top of the lower screen of the deeper well begins. All monitoring wells, particularly multiple wells, must be designed and installed to prevent cross contamination of aquifers.

A single well is usually sufficient if the aquifer is homogeneous, the geology is simple, and there are few contaminants. For most applications at wastewater land treatment facilities, the screened interval should be placed in the uppermost water-bearing zone. The length and positioning of the well screen below land surface must be such that the static water table is never above the uppermost or below the lowermost screen openings at any time of the year (Figure 7-6). Screen settings that do not meet this criteria result in either “dry” wells (i.e., the water table is below the screen, precluding collection of a sample) or a situation where the layer of dissolved contaminants in the groundwater may be above the zone where the sample is collected (i.e. the water table is above the uppermost screen openings). As a rule of thumb, monitoring wells should be screened in the top 10 to 15 feet of this uppermost water-bearing zone, with adequate screen above the water table to allow for seasonal water table fluctuations.

Well diameters are generally 2-inch or 4-inch, whichever is sufficient to accommodate the sampling pump. Two-inch or smaller casing material may be used for wells that are sampled using low-flow sampling methods. One problem with two-inch wells is that pump tests cannot be run. Four-inch wells are generally adequate to run pump tests.

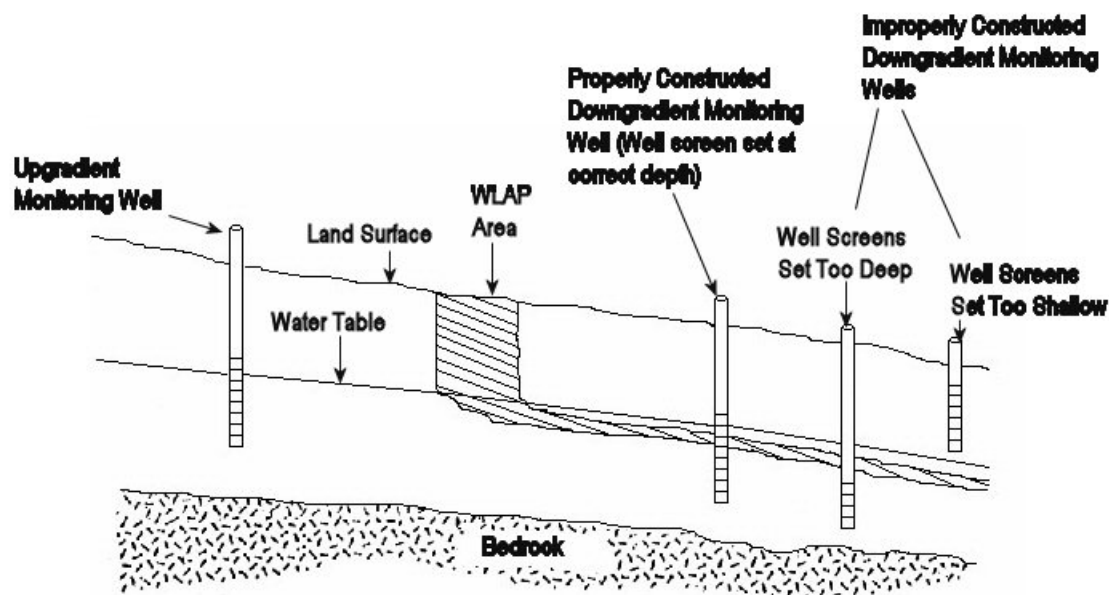


Figure 7-6. Proper and Improper Placement of Screens for Monitoring Wells.

The screen and sand pack material should be selected so that the well can be developed with minimal sediment production over the life of the well. Casing and screen material should be designed to last for the duration of the monitoring program. ASTM D 5092-90 may be used as a guide for selection of casing and screen material. Screen slot size should be determined relative to the interval to be monitored so that the well will produce sediment-free water for the life of the well. (See Driscoll (1986), page 395 and the following pages for further discussion.)

7.7.3.1.3 Casing Materials

A monitoring well is literally an intrusion of foreign material into the subsurface for investigative purposes. It is important to consider chemical reactions between any foreign matter introduced into the aquifer with water chemistry. Typically, care is given to assuring that the well casing and screen materials are compatible with the constituents, which may be present in ground water. Casing material should be selected based on the ground water chemistry to avoid corrosion or chemical degradation.

Additionally, the casing material can influence the water quality of the sample by either sorbing contaminants from ground water or leaching contaminants from the casing material into the ground water sample. Table 7-15 describes several types of casing material and the advantages and disadvantages as they are used in a ground water monitoring network:

- PVC (thermoplastic material) is recommended for inorganic samples. Threaded PVC casing and screen should be used, so that glues are not needed; the volatile and semi-volatile constituents in glues may contaminate samples in certain circumstances.
- Stainless steel is recommended for all ground waters, except acidic waters.
- PTFE (fluoropolymer material, i.e., Teflon®)⁴ is excellent for all types of ground water and all types of chemical constituents.
- Mild steel is not advocated.

Table 7-15. Monitoring Well Casing Materials.

Casing Material	Suggested Use	Advantages	Disadvantages
PVC (thermoplastic materials) minimum schedule 40 recommended	Inorganic	lightweight inexpensive available resistant to acids and alkaloids	less rigid than steel may sorb or leach organic chemicals
Stainless steel 304 or 316 recommended	all ground water except acidic waters	strong rigid resistant to corrosion and oxidation available resistant to organic compounds	heavy expensive may corrode in acidic waters may leach Cr, Fe, Ni
PTFE (fluoropolymer materials - Teflon)	excellent for all types of ground waters and all types of chemical constituents	lightweight inert resistant to most chemicals good for corrosive environments	expensive not readily available
Mild steel not advocated	organic constituents, not recommended for corrosive conditions	strong rigid available	heavy may leach metals not chemically resistant

Other materials used or placed in the borehole should also be made of compatible materials. These materials include welding compounds, bentonite, sand pack materials, centralizers, packers, and grout. Everything placed in the aquifer must come into equilibrium with the

⁴ Teflon® is a registered trademark of E. I. du Pont de Nemours and Company

water in the formation. This may mean contaminants may be precipitated onto the material or may be dissolved in ground water (Pennino, 1988). Ultimately, the presence of the monitoring well can alter the chemistry of the ground water, therefore care should be taken to minimize its impacts.

Knowledge of the water quality of the well, as it is being constructed, is highly desirable. Such knowledge can affect decisions regarding continued construction, modifications in construction, selection of materials, or in the planned operations of the completed well. Common problems related to well construction and water quality monitoring include water zones to be excluded by casing or grouting; selected casing perforation; choice of casing and screen material; and screen placement. Section 7.7.3.1.3 summarizes the applicability, advantages, and disadvantages of well casing materials.

7.7.3.1.4 Seals, Packing and Grouting

An adequate concrete surface seal, generally 3 feet thick, or more, should be provided around the outer protective casing to prevent migration of contaminants from the surface to the well screen. This surface seal should be sloped away from the well casing.

A sanitary seal should be placed above the filter pack. Bentonite chips or pellets are typically used to provide this seal. Grout (cement or bentonite) should be placed above the sanitary seal, up to where the surface seal will begin.

The sand pack should extend above the well screen to prevent entry of grout and/or bentonite into the screened interval. See Figure 7-7 and Figure 7-8, for general monitoring well design for ground water sample collection at wastewater land application sites and as-built construction details for monitoring well at wastewater land application sites respectively. DEQ (March 2001) has step-by-step instructions for monitoring well construction (Appendix B p 59-61) that should be consulted for specifics.

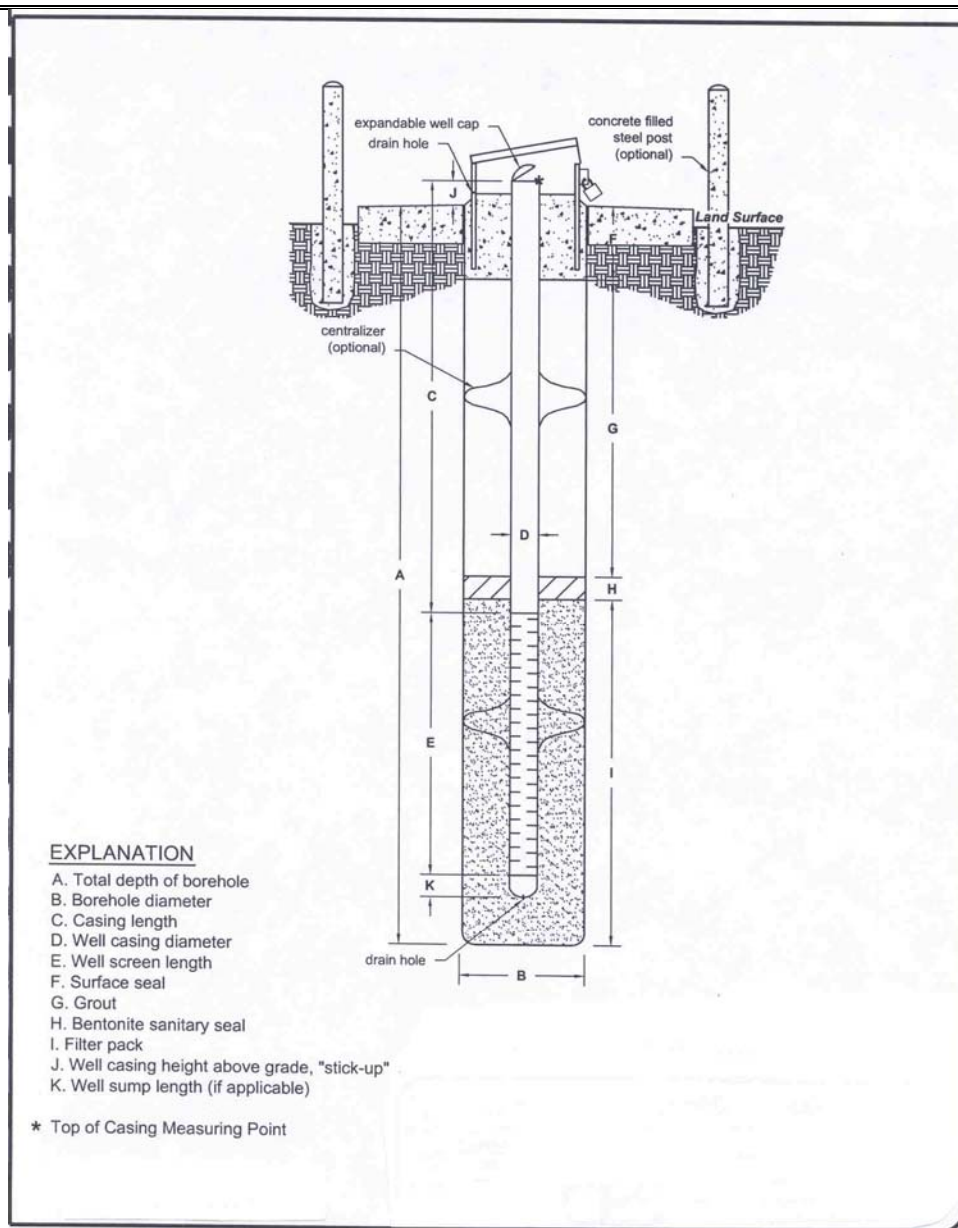


Figure 7-7. General monitoring well design for ground water sample collection at wastewater land application sites.⁵

⁵ Reproduced by permission of Cascade Earth Sciences.

MONITORING WELL CONSTRUCTION DETAILS	
PROJECT NAME _____	BORING/WELL NO. _____
PROJECT NUMBER _____	TOP OF CASING ELEV. AT MARK _____
DATE INSTALLED _____	GROUND SURFACE ELEV. _____
WELL PERMIT NO. _____	DATUM MEAN SEA LEVEL _____
LOCATION _____	
NOTES: _____	

WELL SCHEMATIC
DRAWING NOT TO SCALE

NOTE: Depths and intervals are measured from ground surface.

BORING INFORMATION

A. Total depth ft. 125.0
10" 0-94'

B. Diameter in. 6" 94-125'

Drilling method AIR ROTARY TRICORE

WELL CONSTRUCTION

C. Total Casing length ft. 125.0
Material SCH 40 PVC

D. Diameter (I.D.) in. 2.0

E. Depth to top perforations ft. 102.0

F. Perforated length ft. 20.0
Perforated interval from ft. 102.0
to ft. 122.0
Perforation size 0.010

G. Surface seal from 0.0 ft. to 3.0 ft.
Seal materials CONCRETE

H. Grout from 3.0 ft. to 84.0 ft.
Grout material CEMENT/BENTONITE GROUT

I. Sanitary seal from 84.0 ft. to 99.0 ft.
Seal materials BENTONITE PELLETS

J. Filter pack from 99.0 ft. to 122.0 ft.
10/20 FOR ERODED SAND ZONE
Pack material 20/40 CSSI SAND

K. Bottom zone 3.0 ft.
Material NATIVE FORMATION GRAVEL/SAND

L. Well casing ht. above grade 3.0 ft.

M. Well tail piece length 3.0 in.
Centralizers located at — ft. and — ft.

NOTES: _____

Figure 7-8. As-built construction details for monitoring well at wastewater land application sites.⁶

⁶ Reproduced by permission of Cascade Earth Sciences.

7.7.3.1.5 Monitoring Well Development

During drilling and monitoring well installation, fine sediment particles are forced through the sides of the borehole, which act to clog the formation. This reduces the hydraulic conductivity of the aquifer adjacent to the borehole. The fine materials must be removed from the well intake to assure representative ground water samples will be collected. If the particulate matter is not removed, water moving into the borehole will be turbid and will reduce the integrity of the water sample. Well development also repairs the damage inflicted on the formation during drilling.

All new wells must be developed prior to water quality compliance monitoring. A monitoring well is considered adequately developed when clean, non-turbid water can be removed from the formation. The time interval will vary depending upon the formation material and the amount of damage incurred during drilling. The goal in well development is to continue the process until the water is chemically stable (within 10% per casing volume) and the water is non-turbid.

It is important for the facility to properly develop the wells to assure the wells will yield representative samples. The investment of the monitoring well installation, sampling and analytical costs will not be wasted due to insufficient development time. The additional effort spent on well development will result in samples that are more representative of water chemistry in the formation being monitored.

Table 7-16 describes the common well development techniques. Puls and Powell, (1992), recommend using a water pump which is slowly raised and lowered throughout the length of the screened interval without causing excessive surging. Development techniques which introduce fluids or air into the formation are not recommended due to the possible alteration of ground water chemistry. Bailing, mechanical surging, overpumping and backwashing are all recommended well development techniques. A combination of methods is recommended to assure that adequate surging dislodges the particulates, and that the particulates are physically removed from the well. For wells that are purged using standard pumping methods, purge volumes should include the amount of water contained in the sand pack and inside the casing.

For each monitoring well installed, documentation should be provided for the development method, flow rate, the length of time, and the criteria used for ending the development procedures.

Table 7-16. Well Development Techniques

Method	Description	Advantages	Disadvantages
Bailer	Motion of introducing a bailer into the borehole causes a surge of water to be forced into the formation.	removes fines good for small diameter wells breaks up bridging in formation	not as effective as surge blocks must use sufficiently heavy bailer
Mechanical surging	A block the size of the inner diameter of the well is moved up and down throughout the screened interval. Must be used in conjunction with a bailer to remove fines.	effective at dislodging fines physically breaks up bridges and removes particulates from casing walls good for low yield formations	caution needed to avoid damage to screen and casing caution to prevent plugging screen with particulates may damage filter pack
Overpumping	Pumping at a rate that substantially exceeds the ability of the formation to deliver. The increased velocity causes migration of particles towards the pumping well. Typically used after bailing, or surging and bailing to avoid pump burnout caused by excess particulates in the well bore.	most common least expensive pump removes particulates effective when alternating pump on and off effective when raising and lowering the pump works best in coarse materials minimal time and effort no new fluids introduced	not as vigorous as backwashing can leave the lower portion of large screen intervals undeveloped
Backwashing	The surging action consists of lifting a column of water within the well and then letting it fall back into the well. Reversing the direction of flow breaks down the bridging and the particles are moved back into the well when the pump is restarted.	low cost breaks down bridging in filter pack no new fluids introduced	tends to push fine grained sediments into filter pack potential for air entrainment if air is used unless combined with pumping or bailing, does not remove fines possible disturbance to the gravel pack
Air surging	Air is injected into the well to lift the water to the surface, and then the water is allowed to fall back down the borehole.	develops discrete zones can be used to open fractures	can entrain air permanently into the formation alter the chemistry of the formation water can reduce the permeability
Jetting	Operation of a horizontal jet forces water inside the well screen openings.	develops discrete zones	can drive fines into the formation can alter the chemistry of the formation water can reduce the permeability

Note: A combination of these methods is recommended.

7.7.4 Ground Water Sampling

This section provides guidance on sampling supplies and equipment, well purging, sample collection, sample packing, and decontamination procedures. Guidance regarding documenting of a ground water sampling event can be found in ASTM D 6089 – 97 (2003).

7.7.4.1.1 *Sampling Supplies and Equipment*

Prior planning and careful preparation of field equipment before sampling will ensure good results from the laboratory. The following provides a list of supplies and equipment to be used when sampling ground water.

- disposable gloves
- documentation (forms, log books, and O&M manual, etc.)
- indelible ink pen
- well lock keys
- tape measure
- water level monitoring device and supplies (batteries, chalk and paste as needed)
- field parameter meters with calibration standards
- decontaminated sampling pump with proper tubing and power supply
- bailers with line
- sample bottles
- sample labels
- packing tape
- stop watch
- graduated cylinder
- filtration equipment
- cooler with cold packs or ice
- cleaning buckets and containers
- plastic garbage bags
- small sealable plastic bags
- plastic sheeting
- paper towels and hand soap
- cleaning brushes
- phosphate-free laboratory soap

- deionized organic-free water and hand sprayers
- high purity laboratory grade hexane, acetone, or isopropanol (all available from laboratory supply companies)

Customized kits for sample collection may be supplied by a contract laboratory. These kits include all the items needed for collection and shipment of samples. Those conducting the sampling event should follow laboratory instructions and read container labels. Care should be taken not to discard preservatives that may have already been added to some containers.

If a laboratory sampling kit is not used, those conducting the sampling event should use only new containers or sanitized reusable containers, supplied by a lab, of the appropriate types for the required parameters. Containers should be selected and prepared according to the contract laboratory's instructions. Sample containers should be labeled before sample collection and the type and amount of preservative required should be recorded on each sample label. All sampling equipment, such as bailers, containers, and tubing should be selected and thoroughly cleaned based on the parameters to be monitored. Disposable bailers of the appropriate composition may be used. Teflon™, stainless steel, or glass should be used when sampling for organics, such as solvents and petroleum product contamination. Do not use PVC or other plastics.

7.7.4.1.2 Well Purging

Stagnant water sitting in a well casing is exposed to the atmosphere which can alter the chemistry of the water. Improper well purging can result in gross errors to analytical results (Barcelona, 1989). Wells should be purged until a representative ground water sample can be collected. The exception to this is taking water level measurements, which must be taken *before the well is purged*. To measure static water level, do the following:

From a permanent reference at the top of the well casing, lower a clean weighted steel tape or electric sounder into the well.

15. Record the wet level mark on the tape and subtract it from the reference point to obtain the depth of water. (Use the same reference point each time a water level measurement is made at the well.)

Ground water monitoring wells should be purged for a minimum of three casing volumes and/or until field measurements stabilize. For pH, the following conditions should be met:

- two successive temperature values measured at least five minutes apart are within one degree Celsius of each other,
- pH values for two successive measurements, measured at least five minutes apart, are within 0.2 units of each other
- two successive specific conductance values, measured at least five minutes apart, are within 10% of each other

This procedure will determine when the wells are suitable for sampling for constituents required by the permit. Other procedures, such as low flow sampling, may be considered by DEQ for approval. DEQ (March 2001; Appendix B pp. 40-58) has standard operating

procedures for monitoring well sampling and field parameter acquisition which should be consulted for specifics.

To calculate casing volume, use the following equation (from EPA, 1995 Section 8.0):

$$V_w = 7.48\pi \cdot r^2 h$$

Where:

V_w = well volume (gallons)

r = inside radius of the well (feet)

h = height of the water column (feet). Subtract depth to water from total depth of well

Note: 7.48 gal/ft³ is the conversion factor to express V_w in gallons.

Stabilization of the field parameters especially dissolved oxygen provides assurance that the sample water is representative of aquifer conditions, without disturbing the flow patterns in the aquifer. Purging the well dry and sampling the next day after the well has recovered, is not advisable, since the water entering the borehole will be exposed to the atmosphere and will not be representative of the water in the formation. There are circumstances however, where this may be the only option.

Using low flow pumps for purging generally produces high quality representative samples. Low rate pumping is the preferred method for purging, because bailing may increase turbidity by stirring up sediment in the well. When purging with a pump, slowly lower the pump to just below the top of the standing water column. Continue lowering it as the water level drops and the stagnant water is removed. Barcelona (1989) recommends using low flow rates (0.2-0.3 liters/minute) during both purging and sampling. Purge rates should always be below the rate at which the well was developed. Purge water should be disposed of according to state and federal regulations.

If a pump is not available or cannot be used, use a bottom-emptying bailer to purge and collect samples. To purge using a bailer, lower the bailer slowly, to just below the water level, and retract slowly to reduce aeration and turbidity. Collect the purged water in a graduated bucket to measure a minimum of at least three well volumes, or as discussed above. Bailer lines of braided nylon or cotton cord must not be reused, even if clean, in order to avoid the probability of cross-contamination. Lines must consist of Teflon-coated wire, single strand stainless steel wire, or other monofilament line. Bailers should not be left in wells. Contamination can occur when they are handled outside the wells and placed back inside. Contamination can also occur as a result of deterioration of bailer lines.

7.7.4.1.3 Sample Collection

Proper sample collection is critical to acquiring reliable data which is representative of ground water conditions. Ground water quality samples should be submitted for analysis at a certified laboratory. Samples should be collected according to the laboratory's instructions regarding sample container, preservation, filtering, holding time, and collection procedures. It is standard procedure to follow chain of custody procedures with documentation of the location and handling of the sample from the time of collection until the time of analysis.

Sampling Equipment

It is important to consider the type of sampling equipment and the material of which it is constructed. Dedicated sampling equipment is preferred. Table 7-17 describes the most common and recommended pumps/bailers for ground water quality sampling.

Table 7-17. Ground Water Sampling Equipment

Equipment	Advantages	Disadvantages
Positive Displacement Pump (bladder pump)	Efficient well purging maintains integrity of sample easy to use high quality, consistent, representative samples does not introduce air low flow rates	difficult to decontaminate if the pump and/or tubing is not dedicated limited to depths of < 100 ft (DB says 100's of ft possible) lengthy purge process
Submersible electric pump	efficient purging tool portable variable pump rate reliable	potential for affects on trace organic constituents expensive power source required
Suction Pump (peristaltic pump)	portable, inexpensive, readily available, efficient for purging, not recommended for sampling	useful to depths < 25 ft may cause pH modifications, vacuum can cause loss of dissolved gases and volatile organic constituents silicon tubing has high sorption capacity for organic constituents
Bailer	Inexpensive, portable, no power source, easy to decontaminate	transfer of sample may cause aeration, potential for introducing contamination is high, unsuitable for well purging caution with operation and sample handling time consuming labor intensive
Waterra Inertial Lift Pump	Dedicated Variable flow rates Reliable Simple to Operate Inexpensive tubing and foot valves Manual, electrical power and gas-powered options available	Care must be taken to minimize excessive formation surging Limited to depths of 250 feet.

Note: Methods are listed in order of preference.

Low flow pumps (0.2-0.3 liters/minute) such as the bladder pump, reduce the introduction of oxygen into the sample, which can alter the water chemistry. These pumps also cause the least amount of disturbance to the water in the well and as such are the preferred sampling device. Bailers are not recommended since they disrupt the column of water and re-suspend sediment. Studies show that higher concentrations of metals are detected, mistakenly, in samples collected with bailers, than from samples collected with low flow rates using a peristaltic pump (Puls and Powell, 1992). Ideally the proper sampling equipment which creates the least disturbance to the water in the borehole and formation will yield water quality samples which are representative of true aquifer conditions. Other considerations during sampling include the placement of the intake valve on the pump in order to create the minimum disturbance to the stagnant water above and below the screened interval.

Sampling equipment should be made of inert materials to assure that the sample will not be contaminated during the sample collection process. Table 7-18 describes the recommended material for pumps and bailers based on the type of constituents being analyzed. Teflon is the best inert material for the majority of constituents, and stainless steel is the second choice, (Garner, 1988).

Table 7-18. Sampling Equipment Material.

Material	Advantages	Disadvantages
PTFE (fluoropolymer materials, Teflon)	recommended for organic constituents recommended for corrosive situations where organic constituents are of interest recommended for metals easiest to clean inert least likely to introduce sample bias or imprecision	expensive
Stainless Steel	recommended for organic constituents	may corrode in acidic waters corrosion products may introduce Fe, Cr, Ni expensive
PVC (thermoplastic materials)	lightweight inexpensive resistant to acids recommended for inorganic constituents	not recommended for organic constituents (may sorb or leach) may release Sn or Sb compounds
Mild Steel (low carbon steel, galvanized steel, carbon steel)	readily available	corrosion products Fe, Mn (galvanized Zn, Cd) active adsorption sites for organic constituents and inorganics not recommended for organic constituents not recommended for corrosive conditions

Note: Materials are listed in order of preference.

Ground water samples should be filtered (if necessary), preserved and analyzed in the field as soon as possible after collection to avoid equilibrium changes due to volatilization, sorption, leaching, or degassing, (Barcelona, 1985). Only ground water samples collected for metal or ionic analysis should be filtered. Samples collected for analysis of organic compounds should never be filtered. Traditional filtration protocols for inorganic parameters recommend using an in-line filter with a 0.45 micron pore size. This is also consistent with the *National Pollutant Discharge Elimination System* (NPDES) guidance for metals filtration. Puls and Powell (1992) noted that larger diameter, high capacity filters erroneously produced lower concentrations of contaminants on a routine basis; therefore, they are not recommended.

Sample Collection with Pumps

Low flow pumps (0.2-0.3 liters/minute) such as the bladder pump, reduce the introduction of oxygen into the sample, which can alter the water chemistry. These pumps also cause the least amount of disturbance to the water in the well and as such are the preferred sampling device. When sampling with a portable pump, do the following:

Have sample containers ready before turning on the pump.

16. Lower the pump, slowly, to the desired depth in the well. The placement of the intake valve on the pump should be considered during sampling in order to create the minimum disturbance to the stagnant water above and below the screened interval.
17. Adjust the flow rate to less than 100 mL per minute to reduce agitation.
18. Decontaminate the pump before moving to the next well (see 7.7.4.2).

Sample Collection with Bailers

Bailers are not recommended because they disrupt the column of water and re-suspend sediment. Studies show that higher concentrations of metals are detected, mistakenly, in samples collected with bailers, than from samples collected with low flow rates using a peristaltic pump (Puls and Powell, 1992). But if it is necessary to sample with a bailer, do the following:

Lower the bailer slowly into the well, avoiding agitation, and allow it to fill.

19. Retract the bailer slowly, and discharge the sample carefully into the container until the correct volume has been collected.
20. Add preservative if required, cap the container, and mix according to laboratory instructions. Take precautions to minimize turbidity and sediment in samples. This will minimize the need for filtering.
21. Use purging and sampling techniques previously described to minimize turbidity and agitation of sediment in wells.

In low-yielding wells and those containing high levels of suspended solids, slowly lower a bailer to the lowest standing water level and allow the water to flow into it. Carefully lift the bailer out of the well without allowing it to scrape or bang against the well casing. Allowing the well to recover into the bailer should produce a cleaner sample.

Minimizing Risk of Contamination

There are several ways to minimize risk of contamination during sampling:

- ensuring that all sampling equipment (bailers, tubing, containers, etc.) has been thoroughly cleaned and selected based on compatibility with parameters to be monitored
- using Teflon, stainless steel, or glass when sampling for organics; do not use PVC or other plastics
- using Teflon or glass when sampling for trace metals
- using new sample containers when sampling for compliance monitoring; do not reuse containers
- keeping containers closed before filling, and do not touch the inside of containers or caps
- wearing a new pair of disposable gloves or decontaminated reusable gloves for each sampling site
- placing new plastic sheeting on the ground near each well to hold the sampling equipment; do not step on the sheeting
- placing small samples that require cooling, such as volatile organics, in sealable plastic bags immediately after collection and before submerging in ice
- not smoking while collecting or handling samples, because volatile residues in the smoke can cause sample contamination

- not leaving your vehicle running near the sample collection area, to prevent contamination from engine exhaust fumes
- when using a pump, setting up the generator about 15 feet away and downwind from the well; performing all generator maintenance and fueling off-site and away from samples
- avoiding unnecessary handling of samples
- if dedicated monitoring systems (those permanently installed in wells) are **not** used, cleaning equipment to be reused thoroughly before sampling each well to minimize the risk of cross contamination; bailers left in wells are **not** dedicated systems
- taking enough pre-cleaned equipment to the field to sample each well, so that cleaning between wells is unnecessary; if field cleaning is necessary, an equipment blank may be used to make sure that no contamination results

Blanks should be used to check for contamination. Blanks consist of organic-free deionized water, which must be obtained from laboratories. Types of blanks include the following:

- a *trip blank* (a sealed container of organic-free, deionized water that must be taken to the field and sent back to the lab, unopened, with the samples); include at least one trip blank per cooler for volatiles to check for sample contamination during transportation.
- a *field blank* consists of organic-free deionized water taken to the field and handled in the same manner as the samples to check for contamination from handling, from added preservatives, or from airborne contaminants at the site, which are not from the waste being disposed of at the treatment facility.
- an *equipment blank* (organic-free deionized water, which is passed through the cleaned sampling equipment with added preservatives) may be used to detect any contamination from equipment used for more than one well.

General Procedures for Packing Samples

The following should be done when packing samples prior to shipment by courier or by personal transport to the laboratory:

Line a clean cooler with a large, heavy duty plastic bag, and add bags of ice.

22. Place the properly tagged samples in individual, sealable plastic bags, and seal the bags with chain-of-custody tape to ensure sample integrity.
23. Place bagged samples in the cooler, arranging bags of ice between samples to help prevent breakage; add sufficient ice to maintain the temperature of at 4o C (39.2o F) while the samples are in transit.
24. Enclose the appropriate forms in a sealable plastic bag, place with samples in the chest, and seal the large bag with chain of custody tape.
25. Minimize transport time, and ensure that samples will reach the laboratory without being exposed to temperature variations and without exceeding holding times.

Once the laboratory has completed the sample analysis, a report containing the analytical results will be sent to the person requesting the analysis. Monitoring forms should be carefully filled out, making sure that all information is included and that the data transferred

from laboratory reports are recorded in the correct concentration units. Complete identification information, such as permit number and facility, or permit name, should be included on all correspondence and additional laboratory reports. Forms and laboratory reports should be submitted on time. It is vitally important that the procedures demonstrated be followed carefully by the sampler to avoid costly resampling and to ensure that any ground water contamination is appropriately characterized in the event remediation is necessary.

A facility that utilizes a contractor for ground water sampling should still be familiar with the sampling frequencies and parameters and the general requirements of the sampling protocol. If there are any questions regarding facility specific monitoring requirements, DEQ regional office personnel should be contacted.

7.7.4.2 Decontamination

All sampling equipment that is not dedicated should be routinely decontaminated prior to collecting a sample. Portable sampling systems are used more frequently than dedicated systems because of lower costs. However, because portable systems require using the same equipment from well to well, they increase the possibility of cross contamination unless strict cleaning procedures are followed.

Decontamination between each sampling point eliminates the possibility of cross-contamination, which could introduce a level of error into the sampling results. Decontamination typically involves removing or neutralizing contaminants that have accumulated on the surface of the sampling equipment. Care should be taken not to use cleaning solutions which contain a contaminant of concern. Decontamination should be conducted according to appropriate sampling procedures. Cleaning procedures must be selected based on the equipment composition and the parameters to be monitored.

The following is a summary of minimum cleaning techniques for bailers, applicable for other equipment of the same composition. For stainless steel bailers and equipment, use the following:

- phosphate-free soap and hot tap water wash
- hot tap water rinse
- deionized water rinse
- isopropyl alcohol rinse
- deionized water rinse
- air dry
- Wrap the bailer with aluminum foil or other material to prevent contamination before use. Consider target contaminants when selecting a wrap material.
- To clean Teflon or glass bailers and equipment use the following:
 - phosphate-free soap and hot tap water wash
 - hot tap water rinse

- ten percent nitric acid rinse
- deionized water rinse
- isopropyl alcohol rinse
- deionized water rinse
- air dry

Wrap to prevent contamination before use. Again, consider the target contaminants when selecting wrapping material.

7.7.4.3 Analysis and Methods

Table 7-19. Common Ground Water Analytes and Methods

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Reportable Detection Limits ^{4,5}
Alkalinity	Alk	mg/L	310.1 or 310.2	2320	<1.0 mg/L
pH	pH	S.U.	150.1	4500-H+	> 1, <12
Specific Conductance	SC	umhos/cm	120.1	2510 B	<2 umhos/cm
Total Dissolved Solids (inorganic)	TDS	mg/L	160.2	2540 C	<1.0 mg/L
Static Water Level	SWL	feet	NA ⁶	steel tape, electric tape or other	<0.01 ft
Chemical Oxygen Demand	COD	mg/L	410.2	5220 B	>5.0 mg/L
Nitrate-N	NO3-N	mg/L	352.1	4500-NO3	<0.1 mg/L
Nitrate-N	NO3-N	mg/L	353.2	4500-NO3	< 0.005 mg/L
Total Kjeldahl Nitrogen	TKN-N	mg/L	351.1, 351.2, 351.3 or 351.4	4500-Norg	<0.1 mg/L
Iron, Total Unfiltered	Fe	mg/L	236.1	3500-Fe	<.01 mg/L
Manganese, Total Unfiltered	Mn	mg/L	200.7	3500-Mn	<.001 mg/L
Manganese, Total Unfiltered	Mn	mg/L	243.1	3500-Mn	<.01 mg/L
Sodium	Na	mg/L	273.1	3500-Na	<0.1 mg/L
Potassium	K	mg/L	258.1	3500-K	<0.1 mg/L
Chloride	Cl	mg/L	325.1, 325.2, or 325.3	4500-Cl	<0.9 mg/L
Calcium	Ca	mg/L	215.1 or 215.2	3500-Ca	<0.1 mg/L
Total Organic Carbon	TOC	mg/L		5310 B 1 mg/L	1 mg/L
Total Organic Carbon	TOC	mg/L		5310 C < 1 mg/L	0.05 mg/L
Total Organic Carbon	TOC	mg/L		5310 D < 1 mg/L	0.01 mg/L
Magnesium	Mg	mg/L	242.1	3500-Mg	<0.1 mg/L
Fluoride	F	mg/L	340.1, 340.2, or 340.3	4500-F	<0.1 mg/L
Gross Alpha	A	pCi/l	-	7110	NA
Gross Beta	B	pCi/l	-	7110	NA

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Reportable Detection Limits ^{4,5}
Ammonia	NH3	mg/L	350.1, 350.2, or 350.3	4500-NH3	<0.005 mg/L
Phosphorus Total	P	mg/L	365.4	4500-P	<0.005 mg/L
Dissolved Oxygen	DO	mg/L	360.1 or 360.2	4500-O	<0.1 mg/L
Sulfate	SO4	mg/L	300.0	4500-SO4-2	<2.0 mg/L
Sulfate	SO4	mg/L	375.1, 375.2, or 375.3	4500-SO4-2	<2.5 mg/L
Total Coliform	TC	#/100 ml	p.1143 or p.1083	9221 B 9222 B	NA
Fecal Coliform	FC	#/100 ml	p.1323 or p.1243	9221 C 9222 D	NA
Fecal Streptococcus	FS	#/100 ml	p.1393, p.1363, or p.1433	9230 B 9230 C	NA

Notes:

1. Methods for Chemical Analysis of Water and Wastes. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-CIHL), EPA-600/4-79-020. Revised March 1983 and 1979, where applicable.
2. Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.
3. Bordner, R.H., and J.A. Winter, eds. 1978. "Microbiological Methods for Monitoring the Environment, Water and Waste." Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency. EPA-600/8-78-017.
4. Reportable detection limits used by IDHW-Bureau of Laboratories as of December, 2005.
5. Estimated Method Detection Limit (MDL) achievable by specific analytical method. For EPA methods, use the EPA methods or Environmental Methods Monitoring Index (EMMI) or for Standard Methods use the latest edition of Standard Methods for the Examination of Water & Wastewater.
6. See Sections 4.1.1 through 4.1.10 in EPA (1993).

7.7.5 Soil-Water (Vadose) Monitoring Supplemental Information

7.7.5.1 Analytical Methods

Table 7-20. Common Soil Water Analytes and Methods.

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Reportable Detection Limits ^{4,5}
Alkalinity	Alk	mg/L	310.1 or 310.2	2320	<1.0 mg/L
pH	pH	S.U.	150.1	4500-H+	> 1, < 12
Specific Conductance	SC	umhos/cm	120.1	2510 B	<2 umhos/cm
Total Dissolved Solids (inorganic)	TDS	mg/L	160.2	2540 C	<1.0 mg/L
Chemical Oxygen Demand	COD	mg/L	410.2	5220 B	>5.0 mg/L
Nitrate-N	NO3-N	mg/L	352.1	4500-NO3	<0.1 mg/L
Nitrate-N	NO3-N	mg/L	353.2	4500-NO3	<0.005 mg/L
Total Kjeldahl Nitrogen	TKN-N	mg/L	351.1, 351.2, 351.3 or 351.4	4500-Norg	<0.1 mg/L
Iron, Total Unfiltered	Fe	mg/L	236.1	3500-Fe	<.01 mg/L
Manganese, Total Unfiltered	Mn	mg/L	200.7	3500-Mn	<.001 mg/L
Manganese, Total Unfiltered	Mn	mg/L	243.1	3500-Mn	<.01 mg/L
Sodium	Na	mg/L	273.1	3500-Na	<0.1 mg/L
Potassium	K	mg/L	258.1	3500-K	<0.1 mg/L
Chloride	Cl	mg/L	325.1, 325.2, or 325.3	4500-Cl	<0.9 mg/L
Calcium	Ca	mg/L	215.1 or 215.2	3500-Ca	<0.1 mg/L
Total Organic Carbon	TOC	mg/L		5310 B 1 mg/L	1 mg/L
Total Organic Carbon	TOC	mg/L		5310 C < 1 mg/L	0.05 mg/L
Total Organic Carbon	TOC	mg/L		5310 D < 1 mg/L	0.01 mg/L
Magnesium	Mg	mg/L	242.1	3500-Mg	<0.1 mg/L
Fluoride	F	mg/L	340.1, 340.2, or 340.3	4500-F	<0.1 mg/L
Gross Alpha	A	pCi/l	-	7110	NA
Gross Beta	B	pCi/l	-	7110	NA
Ammonia	NH3	mg/L	350.1, 350.2, or 350.3	4500-NH3	<0.005 mg/L
Phosphorus Total	P	mg/L	365.4	4500-P	<0.005 mg/L
Dissolved Oxygen	DO	mg/L	360.1 or 360.2	4500-O	<0.1 mg/L

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Reportable Detection Limits ^{4,5}
Sulfate	SO ₄	mg/L	300.0	4500-SO ₄ -2	<2.0 mg/L
Sulfate	SO ₄	mg/L	375.1, 375.2, or 375.3	4500-SO ₄ -2	<2.5 mg/L

Notes:

1. Methods for Chemical Analysis of Water and Wastes. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-CIHL), EPA-600/4-79-020. Revised March 1983 and 1979 where applicable.
2. Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.
3. Bordner, R.H., and J.A. Winter, eds. 1978. "Microbiological Methods for Monitoring the Environment, Water and Waste." Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency. EPA-600/8-78-017.
4. Reportable detection limits used by IDHW-Bureau of Laboratories as of December 2005.
5. Estimated Method Detection Limit (MDL) achievable by specific analytical method. For EPA methods, use the EPA methods or Environmental Methods Monitoring Index (EMMI) or for Standard Methods use the latest edition of Standard Methods for the Examination of Water & Wastewater.

7.7.5.2 Data Use and Interpretation

The following guidelines provide the framework to interpret lysimeter data. These guidelines, along with criteria which can be included in permits – such as acceptable ground water constituent concentration at a facility down gradient boundary and acceptable modeled percolate constituent concentration - will aid in determining whether wastewater land treatment management strategies have been effective or require modification.

Due to the potential variability within a site, results from respective sampling events from all lysimeters can be averaged – or a median utilized - to estimate the quality of percolate losses. Acreage weighting of lysimeter results – in proportion to the amount of acreage of a field a particular lysimeter represents - can serve to render the data more spatially representative.

Soil-water percolate is collected from the vadose zone and is not yet considered ground water. Therefore, water quality standards are not directly applicable. However, soil-water percolate can be used for system compliance with some knowledge of the aquifer. By using appropriate values for the properties of the aquifer, impacts to ground water can be estimated based on the quality and quantity of percolate losses. Thresholds of percolate quality and quantity can then be determined which would lead to exceedances of water quality standards, and such thresholds can be used in lieu of ground water limits, whether standards stipulated in regulation or site specific limits determined by DEQ.

7.7.5.2.1 Mass Flux Calculations

Mass flux is the mass of a constituent (NO₃-N in this example) that is percolating below the crop root zone into the underlying aquifer. (See EPA (1993) Section 9.5.1 for solute flux calculation methods; and Section 7.7.5 for methods to estimate soil water flux.)

To calculate a mass flux, both the volume and concentration of the soil-water percolate are needed. If pan lysimeters are used, both volume and concentration of macropore flow (which is not the only component of flow) are presumably already known. If pressure-vacuum samplers are used, the concentration of soil water at the extracting tension is known, but the soil-water percolate volume must be determined by another method (water balance, modeling, soil-moisture status, etc.).

While vadose zone monitoring has potential to answer questions about load to groundwater, instrumentation may not be reliable enough to measure concentration and flow to be used

for estimating potential ground water impacts and compliance with trigger percolate concentration/flow limits in permits. The following discussion and example is presented to outline in concept how lysimeter data could be used notwithstanding its present limitations.

Mass flux should be determined over a period of time and not from one sampling event. A wastewater land treatment example, using data from a pressure-vacuum sampler and soil-water percolate volume calculated using a water balance method, is presented below.

Table 7-20 summarizes example nitrate nitrogen (NO₃-N) lysimeter data. The example land application field has five lysimeters and is sampled quarterly. The evaluation period (EP) for lysimeter data is nine (9) quarters, or 2.25 years, in this example.

Mass flux can only be calculated where there are soil-water percolate losses. Mass flux can be calculated on a pounds per acre (lbs/ac) basis using:

$$M = 0.227 * C_p * Q_p$$

Equation 7-3. Mass flux calculation.

Where:

M = mass flux (lb/ac)

C_p = percolate constituent concentration (mg/L)

Q_p = percolate flow (inch/ac)

MG = million gallons

Note: the factor 0.227 = 0.0272 MG/inch * 8.34 (lb/MG)/(1 mg/L)

For example, first quarter mass losses would be:

$$M = 0.227 * 27.01 \text{ mg/L} * 3.2 \text{ in/ac} = 19.6 \text{ lb/ac}$$

Table 7-21. Quarterly Gravity Lysimeter Monitoring Data for Nitrate-Nitrogen.

Quarter	Month	Soil Water Nitrate-Nitrogen Data: Lysimeters no. 1 - 5					Column I	Column II	Column III
		1	2	3	4	5	Average	Estimated	Mass
		mg/L					Conc	Percolate	Loss
		-----					mg/L	Volume	lb/acre
								inches	
I	January							1.50	
	February							0.70	
	March		48.3	24.5		8.23	27.01	1.00	19.57
II	April							0.27	
	May							0.24	
	June		0.5	0.3	0.1	0.1	0.25	0.21	0.04
III	July							0.24	
	August							0.23	
	September	16.8	31.4	125.1	48	42	52.66	0.23	8.29
IV	October							0.24	
	November							1.04	
	December	9.92	2.57		15.68	3.13	7.83	1.89	5.62
V	January							1.38	
	February							0.85	
	March	14.55	5.1		11.23	17.9	12.20	1.04	9.03
VI	April							0.30	
	May							0.22	
	June	0.2		0.1	0.1	0.1	0.13	0.21	0.02
VII	July							0.20	
	August							0.19	
	September	53.3	37.4	78	82	56.8	61.50	0.23	8.59
VIII	October							0.20	
	November							1.11	
	December	8.88		0.67	9.22	3.3	5.52	2.01	4.15
IX	January							1.42	
	February							0.90	
	March	31.02	22.2	18.9	16.5	28.99	23.52	0.99	17.63
								Total Percolate Volume (inches/acre) ---->	19.03
								Total Nitrate Nitrogen Mass Loss (lb/acre) ----->	72.95
								Average Nitrate Nitrogen Concentration (mg/L) ----->	16.93
Notes: Column III = (Column I) * (sum of percolate volumes in Column II for the Quarter) * (0.2265)									

7.7.5.2.2 Estimation of Ground Water Impact

The potential impact to the underlying ground water can be estimated using constituent mass flux information from lysimeter sampling and basic aquifer characteristics. One important simplifying assumption made here is that there is no sorption, denitrification, precipitation or other constituent losses or sequestration between the bottom of the crop root zone and ground water. All of these treatment processes are possible, which makes this assumption conservative.

Continuing with the same example, the potential ground water impacts at the down gradient boundary of the source area can be estimated using the EPA aquifer-mixing model (EPA, 1981).

$$C_{\text{mix}} = \frac{C_p Q_p + C_{\text{gw}} Q_{\text{gw}}}{Q_p + Q_{\text{gw}}}$$

Equation 7-4. EPA aquifer-mixing equation .

Where:

C_{mix} = constituent concentration in percolate and ground water mixture.

C_p = constituent concentration in percolate.

Q_p = percolate flow.

C_{gw} = constituent concentration in up gradient ground water.

Q_{gw} = ground water flow (volume/time).

Q_{gw} is calculated as shown:

$$Q_{\text{gw}} = kiA$$

Equation 7-5. Calculation of ground water flow, (Q_{gw}).

Where:

k = hydraulic conductivity (in ft/day)

i = gradient (ft/ft)

A = cross sectional area of down gradient boundary perpendicular to ground water flow, and is calculated by:

$$A = L * d$$

Equation 7-6. Calculation of down gradient cross sectional area perpendicular to ground water flow (A).

Where:

L = the length of the down gradient boundary perpendicular to ground water flow

d = the depth of the mixing zone. (special note: do depth calculations in metric units (meters), then convert to feet for remainder of the mixing zone calculations. This is calculated by:

$$d = d_{\alpha V} + d_{IV}$$

Equation 7-7. Calculation of ground water mixing zone depth (d).

(Source: eq. 44, page 45. EPA/540/R-95/128 May 1996. Soil Screening Guidance: Technical Background Document)

Where:

$d_{\alpha v}$ = depth of mixing due to vertical dispersivity, or

$$d_{\alpha v} = (2\alpha_v L)^{0.5}$$

d_{Iv} = depth of mixing due to downward velocity of infiltrating water (Source: eq. 38, page 44. EPA/540/R-95/128 May 1996. Soil Screening Guidance: Technical Background Document)

$$d_{Iv} = d_a \{1 - \exp[(-LI)/(V_s n_e d_a)]\}$$

Where:

α_v = vertical dispersivity (m)

$$\alpha_v = 0.01\alpha_L$$

α_L = longitudinal dispersivity

$$\alpha_L = 0.82(\log_{10} L)^{2.446}$$

(Source: eq. 14b, page 907. Xu, M. and Eckstein, Y. 1995. Ground Water Vol. 33, No. 6; as corrected by Al-Suwaiyan, M.S., 1996, Ground Water Vol. 34 No. 4, page 578.)

Where:

L = length of source parallel to GW flow (meters)

n_e = effective aquifer porosity

d_a = aquifer depth (meters)

I = leachate infiltration rate (meters/yr)

V_s = ground water seepage velocity; (meters/year)

$$V_s = \frac{Ki}{n_e}$$

For this example, we are given the following:

For mixing zone depth calculations:

L = 2087 ft or 636.3 m

n_e = 0.30

d_a = 30 meters

I = 19.03 in/EP * 1 EP/2.25 yr * 1 ft/12 in * 1 m/3.28 ft = 0.218 m/yr

(note EP = evaluation period = 2.25 years in this example)

$\alpha_L = 0.82(\log_{10} 636.3 \text{ m})^{2.446} = 10.2$

$\alpha_v = 0.102$

k = 100 ft/day;

i = 0.0015 ft/ft (7.92 ft/mile); and

$V_s = ki/n_e = (100 \text{ ft/day}) * (0.0015 \text{ ft/ft}) / 0.3 * 365 \text{ day/yr} * 3.28 \text{ m/ft} = 55.6 \text{ m/yr}$

$$d_{IV} = 30 * \{1 - \exp[-(636.3 * 0.218)/(55.6 * 0.3 * 30)]\} = 7.2$$

$$d_{av} = (2 * 0.102 * 636.3)^{0.5} = 11.4$$

$$d = 11.4 + 7.2 = 18.2 \text{ meters or } 61 \text{ ft}$$

Site dimensions: square site of 100 acres (2087 ft by 2087 ft).

In our example,

$$\begin{aligned} Q_{gw} &= kiA = (100 \text{ ft/day}) * (0.0015 \text{ ft/ft}) * (61 \text{ ft}) * (2087 \text{ ft}) \\ &= 19096 \text{ ft}^3/\text{day, or} \\ &= (19096 \text{ ft}^3/\text{day}) * (365 \text{ days/year}) * (1 \text{ acre-ft}/43,560 \text{ ft}^3) \\ &= 160 \text{ acre-ft/year discharging from the down gradient boundary,} \\ &\quad \text{or, for the volume during the evaluation period (EP)} \\ &= 160 \text{ acre-ft/yr} * 2.25 \text{ yr/EP} = 360 \text{ ac-ft/EP} \end{aligned}$$

Q_p is 19.03 in/EP (from Table 7-21). Converting to acre-feet we have:

$$\begin{aligned} Q_p &= (19.03 \text{ in}/[\text{EP acre-year}]) * (100 \text{ acres}) * (1 \text{ acre-feet}/12 \text{ acre-inches}) \\ Q_p &= 158.6 \text{ acre-ft/EP} \end{aligned}$$

$$C_p = 16.93 \text{ mg/L (from Table 7-21).}$$

$$C_{gw} = 3 \text{ mg/L}$$

Putting these values into the EPA mixing zone equation introduced above we have:

$$C_{mix} = \frac{(16.93 \text{ mg/L}) * (158.6 \text{ ac-ft/EP}) + (3.0 \text{ mg/L}) * (360 \text{ ac-ft/EP})}{158.6 \text{ ac-ft/EP} + 360 \text{ ac-ft/EP}}$$

Solving for C_{mix} , the units acre-ft/year cancel to give units of mg/L, or

$$C_{mix} = 7.26 \text{ mg/L}$$

The final ground water $\text{NO}_3\text{-N}$ concentration is estimated to be 7.26 mg/L when the system achieves steady state conditions (which may or may not occur within the evaluation period). This result indicates that while the ground water standard for nitrate will not be exceeded, it does indicate the ground water concentration for nitrate-nitrogen is estimated to increase from 3.0 mg/L to 7.26 mg/L. Although most of the quarterly lysimeter samples exceeded the Maximum Contaminant Level, the ground water standard was not modeled to exceed the ground water standard. Beneficial uses may or may not be impacted, depending upon this modeled change in ground water quality is determined significant by DEQ in the site-specific circumstances.

As discussed at the beginning of 7.3, a maximum percolate constituent concentration (given a constant percolation rate) that will comply with site specific permit conditions can be determined. For example, if a down gradient ground water concentration limit (C_{mix}) is set

at 10 mg/L at the down gradient boundary of the source area, and retaining other values assumed above, we can utilize the mixing zone equation and solve for percolate concentration (C_p).

$$C_p = \frac{[C_{mix} * (Q_p + Q_{gw})] - (C_{gw} * Q_{gw})}{Q_p}$$

$$C_p = \frac{[10 \text{ mg/L} * (158.6 \text{ ac-ft/EP} + 360 \text{ ac-ft/EP})] - (3.0 \text{ mg/L} * 360 \text{ ac-ft/EP})}{158.6 \text{ ac-ft/yr}}$$

$$C_p = 25.9 \text{ mg/L}$$

Given the assumptions above, the percolate could have a value of less than 25.9 mg/L and theoretically not cause exceedance of the ground water standard of 10 mg/L.

7.7.5.2.3 Depth to Water/Travel Time

As discussed in Section 7.1, the estimated travel time of percolate to ground water and other critical factors should be evaluated to help determine whether vadose zone or ground water monitoring would be more practical and appropriate.

Differences in the thickness and composition of the vadose zone affects travel times and for certain constituents the attenuation of constituents percolating through this zone. For example, fractured basalt, if few or thin interbeds are present, provides rapid travel times and negligible treatment. In this case ground water monitoring may still be warranted, even in areas where the vadose zone thickness is substantial.

There are several computer models which may be utilized to characterize unsaturated flow. A simple method of estimating travel time through the vadose zone employs the unit gradient *Lumped Time of Travel Model* (c.f. Guymon, G.L., 1994 pp 103-104). In this model the system is: 1) assumed to be at steady-state with a uniform moisture content, 2) the vadose zone is unlayered, with uniform hydraulic characteristics, and 3) the hydraulic gradient is equal to unity. Under these conditions the hydraulic conductivity is equal to the net percolation rate (Guymon, 1994). The pore velocity (V) can then be estimated with:

$$V = P_o / \theta$$

Equation 7-8. Calculation of pore velocity (V).

Where:

- P_o = net percolation rate (amount of water per unit time; typically expressed in terms such as feet/yr). This variable represents the net amount of water that may be expected to move below the crop root zone. (An example of how P_o may be calculated is found in Guymon, G.L. [1994] pp 81-83.)
- θ = soil moisture content (volume of water/total soil volume) and is expressed in dimensionless terms as a decimal fraction. θ may be obtained indirectly from

tensiometer data, given a soil-specific relationship between θ and soil tension (soil water characteristic curve), from gravimetric analysis of soil cores taken below the root zone soon after an irrigation event, or may be estimated from the use of unsaturated flow computer models. Also, θ may be estimated by use of Gardner's equations (Gardner 1958) (Eq. Equation 7-9 and Equation 7-10) if $\psi \geq -1$ atm of pressure head in the vadose zone. If the latter condition does not hold, other methods should be used (c.f. Guymon 1994 p. 70 ff.)

Guymon also references W.R. Gardner's equations in this model. Using these equations to estimate θ , one must first obtain an estimate of ψ , the pressure head in the vadose zone by using:

$$K(\Psi) = \frac{K_s}{A_k |\Psi|^\beta + 1}$$

Equation 7-9. Gardner equation for unsaturated hydraulic conductivity $K(\psi)$.

Where:

K_s = the saturated hydraulic conductivity; and A_k and β , best fit parameters; are found in Guymon, (1994) p. 70, and are reproduced in Table 7-22.

$K(\psi)$, the hydraulic conductivity at a given pressure head is taken to be equal to P_o .

Equation 7-9 is rearranged to solve for ψ .

$$|\Psi| = e^{\{\ln[(K_s - P_o) / A_k P_o] / \beta\}}$$

Equation 7-10. Solving Equation 9 for soil pressure head (Ψ).

Table 7-22. Approximate Gardner's Parameters for Calculating Unsaturated Hydraulic Conductivity

Soil Texture	K_s (cm·h ⁻¹)	A_k (ψ in cm of water)	β
Sand (dirty)	3.75	$0.132 \cdot 10^{-2}$	2.576
Sandy Loam	1.17	$0.127 \cdot 10^{-4}$	3.731
Silt Loam	0.30	$0.132 \cdot 10^{-4}$	3.135

From Gardner 1958.

Solving for ψ , this value is substituted into Equation 7-11 to obtain θ .

$$\theta = \frac{\theta_s}{A_w |\Psi|^\alpha + 1}$$

Equation 7-11. Gardner equation for calculating soil moisture content (θ).

Where:

θ_s = soil porosity expressed as a decimal. A_w and α , best fit parameters, are found in Guymon (1994) p. 51, and are reproduced in Table 7-24.

Table 7-23. Gardner Parameters for Soils

Soil Texture	θ_s	A_w	α
Sand	0.36	0.0787	0.614
Sandy Loam	0.42	0.0149	0.743
Loam	0.50	0.0121	0.720
Silty Loam	0.46	0.0024	1.079
Clay Loam	0.39	0.0420	0.418
Silty Clay Loam	0.43	0.0128	0.488
Clay	0.44	0.0002	1.007

^aValues are approximate and are primarily for ranges of pressure head between zero and -1 atm. Pore-water pressure units are in cm of water.
From Gardner 1958

Travel time (T) is then estimated by:

$$T = \frac{X}{V}$$

Equation 7-12. Calculation of travel time (T).

Where:

X = thickness of the vadose zone (units of length).

V = pore velocity as defined previously

For example, if a rapid infiltration basin receives 85 inches of wastewater during a year's time and 80 inches is lost to deep drainage then:

$$P_o = K(\psi) = 80 \text{ inches/yr, or } 2.32 \text{ E-2 cm/hr}$$

If the vadose zone is composed of uniform sandy materials, we utilize Equation 7-10. Obtaining $A_k = 0.132 \text{ E-2}$, $\beta = 2.576$, and $K_s = 3.75$ from Table A-10 (Guymon, 1994 p. 70), we solve for ψ :

$$|\Psi| = e^{\{\ln[(3.75 - 2.32 \cdot 10^{-2}) / 0.132 \cdot 10^{-2} * 2.32 \cdot 10^{-2}] / 2.576\}} = 94.2 \text{ cm}$$

Next we utilize Equation 7-11, substituting ψ obtained from Equation A-10, obtaining $\theta_s = 0.36$, $A_w = 0.0787$ and $\alpha = 0.614$ from Guymon (1994) p. 51. This expression is then solved for θ :

$$\theta = \frac{0.36}{0.0787 \cdot 94.2^{0.614} + 1} = 0.16$$

Substituting $P_o = 80 \text{ in/yr}$ and $\theta = 0.16$ into Equation 7-8, we obtain the pore velocity under steady-state conditions:

$$V = 80 / 0.16 = 500 \text{ in/yr or } 42 \text{ ft/yr}$$

If the vadose zone thickness were 50 feet then, using Equation 7-12, the travel time to ground water would be:

$$T = \frac{50}{42} = 1.2 \text{ yr}$$

7.7.6 Soil Monitoring Supplemental Information

7.7.6.1 Soil Sampling Form

Soil Sample Information Sheet

The original will not be returned to you. Keep yellow copy; send original to:
ISU Soil Testing Laboratory, G501 Agronomy, Ames, Iowa 50011.

Date _____

Submitter _____

Address _____

Street or Rural Route

City _____ State _____ Zip Code _____

Phone _____

Lab Space—Do Not Use

payment code _____ x _____

\$ _____ adj _____

CC _____ #C _____

Number of extra copies of report (limit 3) _____ (All copies of report will be sent to submitter.)

Client name _____ Farm is in _____ County.

Note: Recommendations are computer generated. Please use numbers in the boxes below.

Lab no. Do not use	Sample no.	Soil type*	No. of acres	Must be filled in Tillage depth* (inches)	✓ if irr.	Crop information (use crop codes listed below)			Test series requested (use test series codes below)
						Crop to be fertilized		Yield goal bu. or T/A	

* Use soil map units (smu) from Soil Survey Maps

† If using reduced till or no-till, estimate depth of lime incorporation.

Crop codes (use one code per sample)

- | | |
|---------------------------------|-------------------------------|
| 1. Corn or sorghum grain | 8. Oats + forage seeding |
| 2. Irrigated corn grain | 9. Alfalfa topdress |
| 3. Corn or sorghum silage | 10. Bluegrass |
| 4. Corn-soybean sequence | 11. Tall grass: pasture |
| (2-year recommendation— | 12. Tall grass: hay + pasture |
| give yield goal for both crops) | 13. Legume and grass pasture |
| 5. Sunflowers | 14. Sorghum-sudan pasture |
| 6. Wheat | 15. Soybeans |
| 7. Oats: no forage seeding | |

Test series codes (use one code per sample)

1. Regular series (pH, lime, P, K)
2. Regular series + O.M.
3. Regular + Zinc
4. Regular series + O.M. + Zinc
5. pH and lime only
6. Organic Matter only
7. Zinc only

Cost/sample

- | |
|---------|
| \$ 7.00 |
| \$10.00 |
| \$11.00 |
| \$14.00 |
| \$ 4.00 |
| \$ 5.00 |
| \$ 5.50 |

For established charge accounts only:

_____ charge _____ County Extension
 _____ charge _____ County ASC Office
 _____ charge _____
 Company name _____

... and justice for all

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Note: Please provide as much information as possible. Fertilizer recommendations are modified based on soil type. If soil type is not supplied, we will assume that subsoil P and K are very low.

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University Extension

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7.7.6.2 Soil Analytical Methods

Table 7-24. Common Soil Analytes and Methods.

Parameter	Abbreviations	Units	Standard Methods(1)	Comments
pH	--	S.U.	12-2.6; 12-2.7 pp 206-9	pH of saturated paste or 1:1 dilution or WSP6 S-2.10
% Organic Matter	%OM	% of oven dried soil(2)	29-4 pp. 574-7	or WSP S-9.10, S-9.20
Electrical Conductivity	EC	mmhos/cm	10-1; 10-2 (esp. 10-2.3.1); 10-3 (esp. 10-3.3)	E.C. of saturated paste extract Ag handbook 60, p. 8); or WSP S-1.20
% moisture	--	% of oven dried soil(2)	7-2.2 pp. 92-96 gravimetric w/oven drying(2)	
Texture	--	--	USDA 1975(3)	percent sand, silt & clay by hydrometer method ² or pipette method ² compared to textural triangle to determine textural classification
Sodium Absorption Ratio	SAR	--	calculation (see USDA Agricultural Handbook 60)	soluble conc. of Na, Ca, & Mg from saturated paste; WSP S-1.60
Total Kjeldahl Nitrogen	TKN-N	mg/kg	31-1 through 31-4 pp. 595-618	also used is Total N by combustion (AOAC 955.04 1990 edition) or WSP S-8.10
Ammonium Nitrogen	NH4-N	mg/kg	33-1 through 33-7 pp. 643-676	plant available including soluble & exchangeable (See also AOAC 920.03 1990 edition)
Nitrate Nitrogen	NO3-N	mg/kg	33-1 through 33-6 pp. 643-671; 33-8, pp. 363-682	plant available; WSP S-3.10
Sodium	Na	Meq/100 g	9-1 through 9-3 pp. 159-161; 13-4 pp. 238-241	Exchangeable; WSP S-1.60
Potassium	K	Meq/100 g	9-1 through 9-3 pp. 159-161; 13-3 pp. 228-238	Exchangeable; WSP S-5.10
Calcium	Ca	Meq/100 g	9-1 through 9-3 pp. 159-161; 14 pp. 247-262	Exchangeable; WSP S-5.10
Magnesium	Mg	Meq/100 g	9-1 through 9-3 pp. 159-161; 14 pp. 247-262	Exchangeable; WSP S-5.10
Manganese	Mn	mg/kg	18 (esp. 18-3.4) pp. 313-322	DTPA extractable; WSP S-6.10
Iron	Fe	mg/kg	17-4 pp. 308-311	DTPA extractable; WSP S-6.10
Chloride	Cl	meq/100g	26-3 pp. 455-462	water soluble; WSP S-1.40
Sulfate	SO4	mg/kg	28-3 pp. 518-522	water soluble
Cation Exchange Capacity	CEC	meq/100g	8 pp. 149-157	Do not use sum of bases method for CEC with extractable analyses for Ca, Mg, K, and Na.
Phosphorus	P	mg/kg	24-5.1 through 24.5.5 pp. 416-423	Plant Available bicarbonate extraction (Olson) common for neutral to alkaline soils (WSP S-4.10); Use Bray method for acidic soils (S-4.20; Bray P-1).

Notes:

1. Methods of Soil Analysis, Part 2, Chemical and Microbial Properties, 2nd Edition. Edited by A.L. Page, R.H. Miller and D.R. Kenney. ASA SSSA Publication, Madison WI 1982. #9 in monograph Series.
2. Methods of Soil Analysis, Part 1, Physical and Mineralogical Properties, including Statistics of Measurement and Sampling. Edited by C.A. Black et. al. ASA SSSA Publication, Madison WI 1965. #9 in monograph Series.
3. Soil Survey Staff, Soil Taxonomy: A Basic system of Soil Classification for Making and Interpreting Soil Surveys, Soil Conservation Service, USDA, Washington, D.C., Agriculture Handbook 436 (December 1975).
4. Method of analysis should be reported when submitting data to DEQ.
5. Association of Official Analytical Chemists, Official Methods of Analysis (AOAC). 1990 15th edition. All methods cited in this appendix are recommended methods. Other comparable methods yielding the same interpretive results are acceptable unless otherwise stated in the Land Application of Wastewater Permit.
6. Western States Agricultural Laboratory Exchange Program: Suggested Soil and Plant Analytical Methods. Miller, R. O. and Amacher, J. 1994 version 1.00.
7. Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University. Horneck, D. A., Hart, J. M., Topper, K., and Koespell, B., September 1989. Agricultural Experimental Station, Oregon State University, SM 89:4.

7.7.7 Soil Monitoring for Grazing Management

Grazing animals have the potential to adversely impact soil quality by compacting the soil and decreasing infiltration capacity. Decreasing the soils' infiltration capacity decreases the soils' ability to transport water, nutrients, oxygen and carbon dioxide – all essential processes for crop growth. For most soils, soil moisture status is a critical parameter to consider when assessing the potential of soil quality impacts. Generally, the higher the soil moisture content, the greater the potential for the soil to compress under pressure and decrease the soils infiltration capacity. Irrigation as well as precipitation events can change the soil water status. Soils should be monitored, especially after such events, to see whether they are too moist to bear the traffic of grazing animals. Soils can be sampled and evaluated for soil moisture according to the 'feel method' described in Table 7-25 (from Ashley et al. 1997).

“The feel method involves collecting soil samples in the root zone with a soil probe or spade. Then, the water deficit for each sample is estimated by feeling the soil and judging the soil moisture as outlined in” the table below. “Soil samples should be taken at several depths in the root zone at several places in the field.” (Wright and Bergsrud, 1991). Grazing should not be conducted during soil conditions represented by shaded cells in the table.

Table 7-26 shows generalized drainage times for common soil textural classes. Times reflect drainage to field capacity. Unfortunately, field capacity is probably close to optimum moisture for compaction. Soils should be allowed to drain and dry beyond field capacity in the surface to be suitable for grazing. After irrigating, soils should be allowed to drain at least as long as these drainage times. After this, soils should be evaluated by the 'feel method' to determine when grazing would be appropriate. Note that intensive, rotational grazing provides for short intense grazing on small paddocks and minimizes compaction from animals because they are on any one part of the field shorter than extended grazing.

Table 7-25. Feel method chart for estimating soil moisture

(Number indicates inches of water deficit per one foot of soil.)

Shaded cells indicate soil conditions which may be too wet for grazing.

Soil-Moisture Deficiency	Coarse Texture (sand, loamy sand)	Moderately Coarse Texture (sandy loam)	Medium Texture (silt loam, loam)	Fine and Very Fine Texture (clay loam, clay)
0% (Field capacity)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (0.0)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (0.0)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (0.0)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (0.0)
0 – 25%	Tends to stick together slightly, sometimes forms a very weak ball under pressure. (0.0 to 0.2)	Forms weak ball, breaks easily will not slick. (0.0 to 0.4)	Forms a ball, is very pliable, slicks readily if relatively high in clay. (0.0 to 0.5)	Easily ribbons out between fingers, has slick feeling. (0.0 to 0.6)
25 – 50%	Appears to be dry, will not form a ball with pressure. (0.2 to 0.5)	Tends to ball under pressure, but seldom holds together. (0.4 to 0.8)	Forms a ball somewhat plastic, will sometimes slick slightly with pressure. (0.5 to 1.0)	Forms a ball, ribbons out between thumb and forefinger. (0.6 to 1.2)
50 – 75%	Appears to be dry, will not form a ball with pressure. (0.5 to 0.8)	Appears to be dry, will not form a ball. (0.8 to 1.2)	Somewhat crumbly but holds together from pressure. (1.0 to 1.5)	Somewhat pliable, will ball under pressure. (1.2 to 1.9)
75 – 100% (100% is permanent wilt point)	Dry, loose, single-grained, flows through fingers. (0.8 to 1.0)	Dry, loose, flows through fingers. (1.2 to 1.5)	Powdery, dry, sometimes slightly crusted but easily broken down into powdery condition. (1.5 to 2.0)	Hard, baked, cracked, sometimes has loose crumbs on surface. (1.9 to 2.5)

Note: A ball is formed by squeezing a handful of soil very firmly.

Source: Israelsen and Hansen. 1962. *Irrigation Principals and Practices*. Third Edition. New York: John Wiley and Sons, Inc.

Table 7-26. Generalized Drainage Times for Uniform Soil Profiles of Varying Textures

Texture	Drainage Time (Range in days)
Loamy Sand	0.5 - 2
Sandy Loam	3 - 4
Silt Loam	4 - 6
Clay Loam	5 - 7

Carlisle and Phillips, 1976 and Donahue et al., 1977

7.7.8 Wastewater Monitoring Supplemental Information

7.7.8.1 NPDES Compliance Inspection Manual, Chapter 6

Source:

<http://www.epa.gov/compliance/resources/publications/monitoring/cwa/inspections/npdesinspect/npdesmanual.html>

6. FLOW MEASUREMENT

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6. A. Evaluation of Permittee's Flow Measurement

Objectives and Requirements

To comply with the permit requirements established under the National Pollutant Discharge Elimination System (NPDES), the permittee must accurately determine the quantity of wastewater being discharged. Discharge flow measurement is an integral part of the NPDES program, it is important that the inspector evaluate the accuracy of the measurement.

In addition to providing usable information for enforcement purposes, flow measurement serves to:

- Provide data for pollutant mass loading calculations
- Provide operating and performance data on the wastewater treatment plant
- Compute treatment costs, based on wastewater volume
- Obtain data for long-term planning of plant capacity, versus capacity used
- Provide information on Infiltration and Inflow (I/I) conditions, and the need for cost-effective I/I correction

A Flow Measurement Inspection Checklist for the inspector's use appears at the end of this chapter.

Evaluation of Facility-Installed Flow Devices and Data

There are two types of wastewater flow: closed channel flow and open channel flow. Closed channel flow occurs under pressure in a liquid-full conduit (usually a pipe). The facility will usually have a metering device inserted into the conduit which measure flow. Examples of closed channel flow measuring devices are the Venturi meter, the Pitot tube, the paddle wheel, the electromagnetic flowmeter, Doppler, and the transit-time flowmeter. In practice, closed channel flow is normally encountered between treatment units in a wastewater treatment plant, where liquids and/or sludges are pumped under pressure.

Open channel flow occurs in conduits that are not liquid-full. Open channel flow are partially full pipes not under pressure. Open channel flow is the most prevalent type of flow at NPDES-regulated discharge points.

Measure open channel flow using primary and secondary devices. Primary devices are standard hydraulic structures, such as flumes and weirs, that are inserted in the open channel. Inspectors can obtain accurate flow measurements merely by measuring the depth of liquid (head) at the specific point in the primary device. In a weir application, for example, the flow rate is a function of the head of liquid above the weir crest.

Facilities use secondary devices in conjunction with primary devices to automate the flow

Chapter Six

Flow Measurement

measuring process. Typically, secondary devices measure the liquid depth in the primary device and convert the depth measurement to a corresponding flow, using established mathematical relationships. Examples of secondary devices are floats, ultrasonic transducers, bubblers, and transit-time flowmeters. A recorder generally measures the output of the secondary device transmitted to a recorder and/or totalizer to provide instantaneous and historical flow data to the operator. Outputs may also be transmitted to sampling systems to facilitate flow proportioning. Appendix O contains further information on flow measurement devices.

The inspector must assure the permittee obtains accurate wastewater flow data to calculate mass loading (quantity) from measured concentrations of pollutants discharged as required by many NPDES permits. The permittee must produce data that meet requirements in terms of precision and accuracy. Precision refers to data reproducibility or the ability to obtain consistent data from repeated measurements of the same quantity. Accuracy refers to the agreement between the amount of a component measured by the test and the amount actually present.

The accuracy of flow measurement (including both primary and secondary devices) varies widely with the device, its location, environmental conditions, and other factors such as maintenance and calibration. Faulty fabrication, construction, and installation of primary devices are common sources of errors. Improper calibration, misreading, and variation in the speed of totalizer drive motors are major errors related to secondary devices. See Appendix O - "Supplement Flow Measurement Information." When evaluating facility installed devices, the inspector should do the following:

- Verify that the facility has installed primary and secondary devices according to manufacturer's manual instructions.
- Inspect the primary device for evidence of corrosion, scale formation, or solids accumulation that may bias the flow measurement.
- Verify that weirs are level, plumb, and perpendicular to the flow direction.
- Verify that flumes are level, the throat walls (narrowed section of flume) are plumb, and the throat width is the standard size intended.
- Inspect historical records (i.e., strip charts and logs) for evidence of continuous flow measurements. Compare periods of missing data with maintenance logs for explanations of measuring system problems.
- Observe the flow patterns near the primary device for excessive turbulence or velocity. The flow lines should be straight.
- Ensure that the flow measurement system or technique being used measures the entire wastewater discharge as required by the NPDES permit. Inspect carefully the piping to determine whether there are any wastewater diversions, return lines, or bypasses around the system. Make sure the system meets the permit requirement, such as instantaneous or continuous, daily, or other time interval measures. Note anomalies in the inspection report.
- Verify that the site chosen for flow measurement by the facility is appropriate and is in

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accordance with permit requirements.

- Verify that the site chosen by the facility for flow measurement is suitable for type of discharge, flow range, suspended solids concentration, and other relevant factors.
- Verify that the facility has closed channel flow measuring devices where the pipe is always full. If these devices are used, then there must be also a means for the permittee and regulatory agencies/inspector to verify the accuracy of these meters. Primary flow measuring devices such as weirs and flumes are ideal for this purpose.
- Verify that the facility uses appropriate tables, curves, and formulas to calculate flow rates.
- Review and evaluate calibration and maintenance programs for the discharger's flow measurement system. The permit normally requires the facility to check the calibration regularly by the permittee. The facility must ensure that their flow measurement systems are calibrated by a qualified source at least once a year to ensure their accuracy. Lack of such a program is considered unacceptable for NPDES compliance purposes.
- Verify that the facility calibrates flowmeters across the full range of expected flow.
- Verify that primary and secondary devices are adequate for normal flow as well as maximum expected flow. Note whether the flow measurement system can measure the expected range of flow.
- Collect accurate flow data during inspection to validate self monitoring data collected by the permittee.
- The facility must install a flow measuring system that has the capability of routine flow verification by the permittee or appropriate regulatory personnel.

Evaluation of Permittee Data Handling and Reporting

The permittee or facility must keep flow measurement records for a minimum period of three years as the permit requires. Many flow measuring devices produce a continuous flowchart for plant records. Flow records should contain date, flow, time of reading, and operator's name, if applicable the facility must also record. The facility should record maintenance, inspection dates, and calibration data.

The inspector should review the permittee's records and note the presence or absence of data such as:

- Frequency of routine operational inspections
- Frequency of maintenance inspections

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- Frequency of flowmeter calibration (should be as specified in permit, generally at least once per year)
- Irregularity or uniformity of flow.

Evaluation of Permittee Quality Control

The inspection should evaluate following quality control issues during a compliance inspection to ensure:

- Proper operation and maintenance of equipment
- Accurate records
- Sufficient inventory of spare parts
- Valid flow measurement techniques
- Precise flow data
- Adequate frequency of calibration checks.

Evaluate precision of float driven flow meters when flows are stable. Push the float gently downward, hold for 30 seconds, then allowed to return normally. The recorded flow rate should be the same before and after the float was moved. Evaluate accuracy by measuring the instantaneous flow rate at the primary device used at the facility and comparing the value against the value on the meter, graph, integrator, or company record. The difference between two stable totalizer readings (flow is steady for 10 minutes or more) should not exceed ± 10 percent of the instantaneous flow measured at the primary device. Note that most flow measurement systems have both an instantaneous meter readout as well as a totalizer. Both of these devices should be in agreement but that is not always the case due to electrical and other various malfunctions in the flow measuring system. In most cases, the totalizer reading will be what is reported by the permittee. If this is the case, then that device should be checked for accuracy and the permittee's flow measuring system rated accordingly.

In addition, the inspector can evaluate accuracy by installing a second flow measurement system, sometimes referred to as a reference system. Agreement in measured flow rates between the two systems should be within ± 10 percent of the reference rate if all conditions are as recommended for the systems.

6. B. Flow Measurement Compliance

Objectives

The current NPDES program depends heavily on the permittee's submittal of self-monitoring data. The flow discharge measured during the NPDES compliance inspection should verify the flow measurement data collected by the permittee, support any enforcement action that may be necessary, and provide a basis for reissuing or revising the NPDES permit.

Flow Measurement System Evaluation

The responsibility of the inspector includes collecting accurate flow data during the inspection and validating data collected during the permittee's self-monitoring.

The NPDES inspector must check both the permittee's flow data and the flow measurement system to verify the permittee's compliance with NPDES permit requirements. When evaluating a flow measurement system, the inspector should consider and record findings on the following:

- Whether the system measures the entire discharge flow.
- The system's accuracy and good working order. This will include a thorough physical inspection of the system and comparison of system readings to actual flow or those obtained with calibrated portable instruments.
- The need for new system equipment.
- The existence or absence of a routine calibration and maintenance program for flow measurement equipment.

If the permittee's flow measurement system is accurate within ± 10 percent, the inspector should use the installed system. If the flow sensor or recorder is found to be inaccurate, the inspector should determine whether the equipment can be corrected in time for use during the inspection. If the equipment cannot be repaired in a timely manner, use the portable flow sensor and recorder used to assess the accuracy of the permittee's system for the duration of the inspection. If nonstandard primary flow devices are being used, request the permittee to supply data on the accuracy and precision of the method being employed.

For flow measurement in pipelines, the inspector may use a portable flowmeter. The inspector should select a flowmeter with an operating range wide enough to cover the anticipated flow to be measured. The inspector should test and calibrate the selected flowmeter before use. The inspector should select the site for flow measurement according to permit requirements and install the selected flowmeter according to the manufacturer's specifications. The inspector should use the proper tables, charts, and formulas as specified by the manufacturer to calculate flow rates.

Four basic steps are involved in evaluating the permittee's flow measurement system:

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- Physical inspection of the primary device
- Physical inspection of the secondary device and ancillary equipment
- Flow measurement using the primary/secondary device combination of the permittee
- Certification of the system using a calibrated, portable instrument.

The following sections present, procedures for inspecting the more common types of primary and secondary devices, for measuring flow using common permanent and portable systems, and for evaluating flow data. Please note that the number of primary/secondary device permutations is limitless; therefore, it is not feasible to provide procedures for all systems. When encountering systems other than those discussed here the inspector should consult the manufacturers manual/personnel for advice before preparing a written inspection procedure.

Primary Device Inspection Procedures

The two most common open channel primary devices are sharp-crested weirs and Parshall flumes. Common sources of error when using them include the following:

- Faulty fabrication—weirs may be too narrow or not "sharp" enough. Flume surfaces may be rough, critical dimensions may exceed tolerances, or throat walls may not be vertical.
- Improper installation—the facility may install weirs and flumes too near pipe elbows, valves, or other sources of turbulence. The devices may be out of level or plumb.
- Sizing errors—the primary device's recommended applications may not include the actual flow range.
- Poor maintenance—primary devices corrode and deteriorate. Debris and solids may accumulate in them.

Specific inspection procedures for the sharp-crested weir, the Parshall flume, and the Palmer-Bowlus flume devices follow.

Sharp-Crested Weir Inspection Procedures

- Inspect the upstream approach to the weir.
 - Verify that the weir is perpendicular to the flow direction.
 - Verify that the approach is a straight section of conduit with a length at least 20 times the maximum expected head of liquid above the weir crest.
 - Observe the flow pattern in the approach channel. The flow should occur in smooth stream lines without velocity gradients and turbulence.
 - Check the approach, particularly in the vicinity of the weir, for accumulated solids,

debris, or oil and grease. The approach must have no accumulated matter.

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- Inspect the sharp-crested weir.
 - Verify that the crest of the weir is level across the entire conduit traverse.
 - Measure the width of the weir crest. The edge of the weir crest should be no more than 1/8-inch thick.
 - Make certain the weir crest corresponds to zero gauge elevation (zero output on the secondary device).
 - Measure the angle formed by the top of the crest and the upstream face of the weir. This angle must be 90 degrees.
 - Measure the chamfer (beveled edge) on the downstream side of the crest. The chamfer should be approximately 45 degrees.
 - Visually survey the weir-bulkhead connection for evidence of leaks or cracks which permit bypass.
 - Measure the height of the weir crests above the channel floor. The height should be at least twice the maximum expected head (2H) of liquid above the crest.
 - Measure the width of the end contraction. The width should be at least twice the maximum expected head (2H) of the liquid above the crest.
 - Inspect the weir for evidence of corrosion, scale formation, or clinging matter. The weir must be clean and smooth.
 - Observe flow patterns on the downstream side of the weir. Check for the existence of an air gap (ventilation) immediately adjacent to the downstream face of the weir. Ventilation is necessary to prevent a vacuum that can induce errors in head measurements. Also ensure that the crest is higher than the maximum downstream level of water in the conduit.
 - Verify that the nappe is not submerged and that it springs free of the weir plate.
 - If the weir contains a V-notch, measure the apex angle. The apex should range from 22.5 degrees to 90 degrees. Verify that the head is between 0.2 and 2.0 feet. The weir should not be operated with a head of less than 0.2 feet since the nappe may not spring clear of the crest.

King's *Handbook of Hydraulics*, 1963, frequently referenced throughout this chapter, provides a detailed discussion on weirs.

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Parshall Flume Inspection Procedures

- Inspect the flume approach.
 - The flow pattern should be smooth with straight stream lines, be free of turbulence, and have a uniform velocity across the channel.
 - The upstream channel should be free of accumulated matter.
- Inspect the flume.
 - The flume should be located in a straight section of the conduit.
 - Flow at the entrance should be free of "white" water.
 - The flume should be level in the transverse and translational directions.
 - Measure the dimensions of the flume. Dimensions are strictly prescribed as a function of throat width (see Figure I-5 in Appendix O for critical dimensions).
 - Measure the head of liquid in the flume and compare with the acceptable ranges in Table I-4 in Appendix O.
- Inspect the flume discharge.
 - Verify that the head of water in the discharge is not restricting flow through the flume. The existence of a "standard wave" is good evidence of free flow and verifies that there is no submergence present.
 - Verify whether submergence occurs at near maximum flow (e.g., look for water marks on the wall).

Palmer-Bowlus Flume Inspection Procedures

- Inspect the flume approach as outlined above (these flumes are seldom used for effluent flow measurement).
- Inspect the flume.
 - The flume should be located in a straight section of the conduit.
 - Flow at the entrance should be free of "white" water.
 - Observe the flow in the flume. The profile should approximate that depicted in Figure I-8 in Appendix O.
 - The flume should be level in the transverse direction and should not exceed the translational slope in Table I-6 in Appendix O.

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- Measure the head of water in the flume. Head should be within the ranges specified in Table I-6 in Appendix O.
- Inspect the flume discharge.
- Verify that free flow exists. Look for the characteristic "standing wave" in the divergent section of the flume.

Venturi Meter Inspection Procedures

- Verify that the facility installed the Venturi meter according to manufacturer's instructions.
- Verify that the facility installed the Venturi meter downstream from a straight and uniform section of pipe, at least 5 to 20 diameters, depending on the ratio of pipe to throat diameter and whether straightening vanes are installed upstream. (Installation of straightening vanes upstream will reduce the upstream piping requirements.)
- Verify that the pressure measuring taps are free of debris and are not plugged.
- Calibrate the Venturi meter in place by either the volumetric method or the comparative dye dilution method to check the manufacturer's calibration curve or to develop a new calibration curve.

Secondary Device Inspection Procedures

The following are common sources of error in the use of secondary devices:

- Improper location—gauge is located in the wrong position relative to the primary device.
- Inadequate maintenance—gauge is not serviced regularly.
- Incorrect zero setting—zero setting of gauge is not the zero point of the primary device.
- Operator error—human error exists in the reading.

Specific inspection procedures follow.

Flow Measurement in Weir Applications

- Determine that the head measurement device is positioned 3 to 4 head lengths upstream of a weir.
- Verify that the zero or other point of the gauge is equal to that of the primary device.

The inspector should use an independent method of measuring head, such as with a yardstick or carpenter's rule (be sure to take your measurement at least four times the maximum head upstream and from the weir and convert to nearest hundredth of a foot). To determine flow

rate, use the appropriate head discharge relationship formula (see Table I-1 in Appendix O).

Flow Measurement in Parshall Flume Applications

Flow Measurement—Free-Flow Conditions.

- Determine upstream head (H_a) using staff gauge.
 - Verify that staff gauge is set to zero head. Use either a yardstick or carpenter's rule.
 - Verify that staff gauge is at proper location (two-thirds the length of the converging section back from the beginning of the throat).
 - Read to nearest division the gauge division at which liquid surface intersects gauge.
 - Read H_a in feet from staff gauge.
- To determine flow rate, use Figure I-6 in Appendix O in the unit desired, use tables published in flow measurement standard references, or calculate using the coefficients in Table I-5 in Appendix O.

Flow Measurement—Submerged-Flow Condition.

Generally it is difficult to make field measurements with submerged-flow conditions. In cases when measurements can be obtained (using a staff or float gauge), the procedures listed below should be followed:

- Determine upstream head using staff or float gauge.
 - Read to nearest division and, at the same time as for H_b , the gauge division at which liquid surface intersects gauge.
 - Calculate H_a from gauge reading.
- Determine downstream head (H_b) using staff or float gauge.
 - H_b refers to a measurement at the crest.
 - Read to nearest division, and at the same time as for H_a , the gauge division at which liquid surface intersects gauge.
 - Calculate H_b from staff reading.

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Flow Measurement

- Determine flow rate.
 - Calculate percent submergence:

$$\left[\frac{H_b}{H_a} \right] \times 100.$$

- Consult Table I-6 in Appendix O.
- When a correction factor is obtained, use H_b and find free-flow from Figure I-6.
- Multiply this free-flow value by the correction factor to obtain the submerged flow.

The inspector may use an independent method of measuring head, such as a yardstick or carpenter's rule at the proper head measurement point. Because of the sloping water surface in the converging section of a flume, it is essential that the proper head measurement point be used.

Flow Measurement in Palmer-Bowlus Flume Applications

- Obtain head measurements as in the Parshall Flume application, using the secondary device. The head is the height of water above the step. The total depth upstream of the step is not the head.
- Refer to manufacturer-supplied discharge tables to convert head measurements to flow data. Palmer-Bowlus flumes, unlike Parshall flumes, are not constructed to standard dimensional standards. The inspector must not use discharge tables supplied by other manufacturers.

Verification

Most flow measurement errors result from inadequate calibration of the flow totalizer, and recorder. If the inspector has determined that the primary device has been installed properly, verification of the permittee's system is relatively simple. Compare the flow determined from the inspector's independent measurement to the flow of the permittee's totalizer or recorder. The inspector's flow measurements should be within 10 percent of the permittee's measurements to certify accurate flow measurement. Optimally, flow comparisons should be made at various flow rates to check system accuracy.

When the permit requires that the daily average flow be measured by a totalizing meter, the inspector should verify that the totalizer is accurate, i.e., properly calibrated. This can be done during a period of steady flow by reading the totalizer and at the same time starting a stopwatch. Start the stopwatch just as a new digit starts to appear on the totalizer. After 10 to 30 minutes, the totalizer should be read again; just as a new digit begins to appear, the stop watch is read. Subtract the two totalizer readings to determine, the total flow over the measured time period. Calculate the flow rate in gallons per minute by using the time from the stop watch. Compare this flow rate to the flow determined by actual measurement of the head

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made at the primary device at the time interval. Consider the calibration of the totalizer satisfactory if the two flows are within 10 percent of each other, when the actual measured flow is used as the known value, or divisor, in the percent calculation.

6. C. References and Flow Measurement Inspection Checklist

References

- Associated Water and Air Resource Engineers, Inc. 1973. *Handbook for Industrial Wastewater Monitoring*. USEPA, Technology Transfer.
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- ISCO. 1985. *Open Channel Flow Measurement Handbook*, Lincoln, Nebraska. (Contains tables of various flow measurement devices.)
- King, H.W., and E.F. Brater. 1963. *Handbook of Hydraulics*. 5th ed. New York: McGraw-Hill Book Co. (contains tables of various flow measurement devices.)
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- Robinson, A.R. 1965. *Simplified Flow Corrections for Parshall Flumes Under Submerged Conditions*, Civil Engineering, ASCE.
- Shelley, P.E., and G.A. Kirkpatrick. 1975. *Sewer Flow Measurement; A State of the Art Assessment*, U.S. Environmental Protection Agency, EPA-600/2-75-027.
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- Smoot, G.F. 1974. *A Review of Velocity-Measuring Devices*. U.S. Department of the Interior (USDI), United States Geological Survey (USGS). Open File Report, Reston, Virginia.
- Stevens. *Water Resources Data Book*, Beaverton, Oregon. (Contains tables of various flow measurement devices.)
- Thorsen, T., and R. Oden. 1975. "How to Measure Industrial Wastewater Flow," *Chemical Engineering*, 82(4): 95-100.

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U.S. Department of Commerce, National Bureau of Standards. 1975. *A Guide to Methods and Standards for the Measurement of Water Flow*. COM-75-10683.

U.S. Department of the Interior (USDI), Bureau of Reclamation. 1967. *Water Measurement Manual*, 2nd Ed. (Contains tables of various flow measurement devices.)

U.S. Environmental Protection Agency, Office of Water Enforcement and Permits Enforcement Division. September 1981. *NPDES Compliance Flow Measurement Manual*.

FLOW MEASUREMENT INSPECTION CHECKLIST

A. GENERAL

Yes	No	N/A	1. a. Primary flow measuring device properly installed and maintained.
Yes	No	N/A	b. Flow measured at each outfall? _____ Number of outfalls? _____
Yes	No	N/A	c. Is there a straight length of pipe or channel before and after the flowmeter of at least 5 to 20 diameters?
Yes	No	N/A	d. If a magnetic flowmeter is used, are there sources of electric noise in the near vicinity?
Yes	No	N/A	e. Is the magnetic flowmeter properly grounded?
Yes	No	N/A	f. Is the full pipe requirement met?
Yes	No	N/A	2. a. Flow records properly kept.
Yes	No	N/A	b. All charts maintained in a file.
Yes	No	N/A	c. All calibration data entered into a log book.
Yes	No	N/A	3. Actual discharged flow measured.
Yes	No	N/A	4. Effluent flow measured after all return lines.
Yes	No	N/A	5. Secondary instruments (totalizers, recorders, etc.) properly operated and maintained.
Yes	No	N/A	6. Spare parts stocked.
Yes	No	N/A	7. Effluent loadings calculated using effluent flow.

B. FLUMES

Yes	No	N/A	1. Flow entering flume reasonably well-distributed across the channel and free of turbulence, boils, or other disturbances.
Yes	No	N/A	2. Cross-sectional velocities at entrance relatively uniform.
Yes	No	N/A	3. Flume clean and free of debris and deposits.
Yes	No	N/A	4. All dimensions of flume accurate and level.
Yes	No	N/A	5. Side walls of flume vertical and smooth.
Yes	No	N/A	6. Sides of flume throat vertical and parallel.
Yes	No	N/A	7. Flume head being measured at proper location.
Yes	No	N/A	8. Measurement of flume head zeroed to flume crest.
Yes	No	N/A	9. Flume properly sized to measure range of existing flow.
Yes	No	N/A	10. Flume operating under free-flow conditions over existing range of flows.
Yes	No	N/A	11. Flume submerged under certain flow conditions.
Yes	No	N/A	12. Flume operation in variably free-flow.

FLOW MEASUREMENT INSPECTION CHECKLIST
(Continued)

C. WEIRS

Yes	No	N/A	1. What type of weir does the facility use?
Yes	No	N/A	2. Weir exactly level.
Yes	No	N/A	3. Weir plate plumb and its top and edges sharp and clean.
Yes	No	N/A	4. Downstream edge of weir is chamfered at 45°.
Yes	No	N/A	5. Free access for air below the nappe of the weir.
Yes	No	N/A	6. Upstream channel of weir straight for at least four times the depth of water level and free from disturbances.
Yes	No	N/A	7. Distance from sides of weir to side of channel at least 2H.
Yes	No	N/A	8. Area of approach channel at least (8 × nappe area) for upstream distance of 15H.
Yes	No	N/A	9. If not, is velocity of approach too high?
Yes	No	N/A	10. Head measurements properly made by facility personnel.
Yes	No	N/A	11. Leakage does not occur around weir.
Yes	No	N/A	12. Use of proper flow tables by facility personnel.

D. OTHER FLOW DEVICES

	1. Type of flowmeter used:
	2. What are the most common problems that the operator has had with the flowmeter?
	3. Measured wastewater flow: _____ mgd; Recorded flow: _____; Error _____ %

E. CALIBRATION AND MAINTENANCE

Yes	No	N/A	1. Flow totalizer properly calibrated.
			2. Frequency of routine inspection by proper operator: _____/day.
			3. Frequency of maintenance inspections by plant personnel: _____/year.
Yes	No	N/A	4. Flowmeter calibration records kept. Frequency of flowmeter calibration: _____/month.
Yes	No	N/A	5. Flow measurement equipment adequate to handle expected ranges of flow rates.
Yes	No	N/A	6. Calibration frequency adequate.

Table 7-27. Wastewater Monitoring for Industrial Wastewater Land Application Facilities

Frequency	Monitoring Point	Description/Type of Monitoring	Parameters
Daily	Flow meter	Flow of wastewater into land application system	Volume (million gallons and acre-inches) to each hydraulic management unit, record monthly and annually
Annually	Each hydraulic management unit	Calculate non-growing season wastewater loading rate	Million gallons & Inches/ non-growing season
Annually	Each hydraulic management unit	Calculate growing season wastewater loading rate	Million gallons & Inches/ growing season
Annually	All flow measurement locations.	Flow measurement calibration of all flows to land application.	Document the flow measurement calibration of all flow meters and pumps used directly or indirectly measure all wastewater, tail water, flushing water, and supplemental irrigation water flows applied to each hydraulic management unit.
Annually	All supplemental irrigation pumps directly connected to the wastewater distribution system.	Backflow testing	Document the testing of all backflow prevention devices for all supplemental irrigation pumps directly connected to the wastewater distribution system(s). Report the testing date(s) and results of the test (pass or fail). If any test failed, report the date of repair or replacement of backflow prevention device, and if the repaired/replaced device is operating correctly.
Monthly	Effluent to land application	Wastewater quality into land application system – 24-hr. Composite	Chemical Oxygen Demand, Total Kjeldahl Nitrogen, Ammonia-Nitrogen, Nitrite + Nitrate-Nitrogen, Total Phosphorous, Chloride, Electrical Conductivity, Potassium, pH
Quarterly	Effluent to land application	Wastewater quality into land application system	Total Dissolved Inorganic Solids (TDIS) – See Table B-1. Submit analysis of individual ions in addition to TDIS.
Quarterly (for the first year only, 4 sample events)	Effluent to land application	Wastewater quality into land application system – 24-hr. composite.	Total Dissolved Solids (TDS), Volatile Dissolved Solids (VDS) for NVDS determination (i.e. NVDS = TDS – VDS)
Quarterly (for the first year only, 4 sample events)	Effluent to land application	Grab sample for bacteria	Colony numbers for Fecal Coliform, Total Coliform, Fecal Streptococcus and Pseudomonas, standard presence / absence test for Listeria (if present, determine specific type)
Daily	Flow meter or Calibrated Pump Rate	Supplemental Irrigation Water	Volume (million gallons and acre-inches) to each Hydraulic Management Unit , report monthly and annually.
Twice per year (May and Oct)	Nearest Surface Water – DEQ shall review and approve locations prior to initial sampling event.	Grab samples of surface water upstream and downstream from land application site.	Nitrate + Nitrite Nitrogen, Total Phosphorous, , Total Dissolved Solids, , Total Kjeldahl Nitrogen
Twice per year (May and Oct)	Supplemental Irrigation at diversions	Grab sample	Nitrate + Nitrite Nitrogen, Total Phosphorous, Total Dissolved Solids, , Chloride, Total Kjeldahl Nitrogen

Table 7-28. Wastewater Monitoring for Municipal Wastewater Land Application Facilities.

Frequency	Monitoring Point	Description and Type of Monitoring	Parameters
Daily (when land applying)	Discharge Point of Wastewater to Land Application (Flow Meter)	Volume of Wastewater land applied	Gallons/Month and acre-inches/month applied to each Hydraulic Management Unit
Annually	Each hydraulic management unit	Calculate non-growing season wastewater loading rate	Million gallons & Inches/ non-growing season
Annually	Each hydraulic management unit	Calculate growing season wastewater loading rate	Million gallons & Inches/ growing season
Annually	All flow measurement locations.	Flow measurement calibration of all flows to land application.	Document the flow measurement calibration of all flow meters and pumps used directly or indirectly measure all wastewater, tail water, flushing water, and supplemental irrigation water flows applied to each hydraulic management unit.
Annually	All supplemental irrigation pumps directly connected to the wastewater distribution system.	Backflow testing	Document the testing of all backflow prevention devices for all supplemental irrigation pumps directly connected to the wastewater distribution system(s). Report the testing date(s) and results of the test (pass or fail). If any test failed, report the date of repair or replacement of backflow prevention device, and if the repaired/replaced device is operating correctly.
Monthly (when land applying)¹	Discharge Point of Wastewater to Land Application	grab sample	Total Kjeldahl nitrogen, nitrate+nitrite-nitrogen, TDS, pH, COD, total phosphorus
Daily (when land applying)	Flow Meter or Calibrated Pump Rate	Supplemental Irrigation Water	Gallons/Month and acre-inches/month applied to each Hydraulic Management Unit
Annually	Supplemental Irrigation Water at diversions	Grab Sample	Total Kjeldahl nitrogen, nitrate+nitrite-nitrogen, TDS, total phosphorus
During Application Season For total coliform, monitoring frequency depends on level of treatment. 1. 2.2 / 100 ml. - Twice Weekly 2. 23 / 100 ml. - Weekly 3. 230 / 100 ml. - Twice Monthly	Discharge Point of Wastewater to Land Application	grab sample	Total Coliform
Twice per year (May and Oct)	Nearest Surface Water – DEQ shall review and approve locations prior to initial sampling event.	Grab samples of surface water upstream and downstream from land application site.	Nitrate + Nitrite Nitrogen, Total Phosphorous, , Total Dissolved Solids, Total Kjeldahl Nitrogen

Note:

1) Sampling frequency may be reduced to twice per season if the system nitrogen loading rate is less than 75% of the nitrogen permit limit (125% of crop uptake. The months in which the samples are to be taken should be specified in the permit and/or O&M manual (for example, July and September). This monitoring reduction should not be allowed for municipal systems with industrial users.

Table 7-29. Wastewater Analyses.

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Comments
Total Flow	--	MGD	--	meter measurement	
pH	--	S.U.	150.1	4500-H+	
Dissolved Oxygen	DO	mg/L	360.1 or 360.2	4500-O	
Chemical Oxygen Demand	COD	mg/L	410.1 see comments	5220 B	for COD>50 mg/L & Cl < 2000 mg/L
Chemical Oxygen Demand	COD	mg/L	410.2 see comments	5220 B	for COD 5-50 mg/L
Chemical Oxygen Demand	COD	mg/L	410.3 see comments	5220 B	for COD > 250 mg/L & Cl > 1000 mg/L
Biological Oxygen demand	BOD	mg/L	405.1	5210 B	
Electrical Conductivity	EC	umhos/cm	120.1	2510 B	
Total Dissolved Solids (or Total Filterable Residue)	TDS	mg/L	160.25	2540 C5	This analysis includes both organic and inorganic TDS5
Volatile Dissolved Solids (Total Nonfilterable Dissolved Residue)	VDS	mg/L	160.45	2540 E5	See footnote #5
Fixed Dissolved Solids	FDS	mg/L		2540 E (20 th Ed.)	
Non Volatile Dissolved Solids	NVDS	mg/L			Calculated by subtracting VDS from TDS ⁵
Total Suspended Solids (or Total Non-Filterable Residue)	TSS	mg/L	160.1	2540 D	
Total Settleable Solids	SS	mg/L	160.5	2540 F	
Ammonia Nitrogen	NH3-N	mg/L	350.1, 350.2, or 350.3	4500-NH3	(See also AOAC4 920.03, 1990 edition)
Total Kjeldahl Nitrogen	TKN	mg/L	351.1, 351.2, 351.3, or 351.4	4500-Norg	(See also AOAC4 955.04, 1990 edition)
Nitrate + Nitrite Nitrogen	NO3 + NO2	mg/L	353.1, 353.2 or 353.3	4500-NO3 + 4500-NO2	(See also AOAC4 958.01, 1990 edition)

Parameter	Abbreviations	Units	EPA ¹	Standard Methods ²	Comments
Total Phosphorus	P	mg/L	365.4	4500-P	(See also AOAC4 965.09, 1990 edition)
Sodium	Na	mg/L	273.1	3500-Na	(See also AOAC4 965.09, 1990 edition)
Potassium	K	mg/L	258.1	3500-K	(See also AOAC4 965.09, 1990 edition)
Calcium	Ca	mg/L	215.1 or 215.2	3500-Ca	(See also AOAC4 965.09, 1990 edition)
Magnesium	Mg	mg/L	242.1	3500-Mg	(See also AOAC4 965.09, 1990 edition)
Iron	Fe	mg/L	236.1	3500-Fe	(See also AOAC4 965.09, 1990 edition)
Manganese	Mn	mg/L	243.1	3500-Mn	(See also AOAC4 965.09, 1990 edition)
Oil & Grease	--	mg/L	413.1 or 413.2	5520	
Alkalinity	Alk	mg/L	310.1 or 310.2	2320	
Chloride	Cl	mg/L	325.1, 325.2, or 325.3	4500-Cl-	
Chlorine Residual	Clres	mg/L	330.1, 330.2, 330.3, 330.4 or 330.5	4500-Cl	
Fluoride	F	mg/L	340.1, 340.2 or 340.3	4500-F-	
Fecal Coliform	FC	#/100 ml	p. 1323 or p. 1243	9221 C 9222 D	
Total Coliform	TC	#/100 ml	p. 1143 or p. 1083	9221 B 9222 B	
Total Coliform in presence of chlorine	TC	#/100 ml	p. 1143 or p. 1113	9221 B 9222 B+B.5c	
Fecal Streptococcus	FS	#/100 ml	p. 1393, p. 1363 or p. 1433	9230 B 9230C	
Gross alpha	--	pCi/L	--	7110	
Gross beta	--	pCi/L	--	7110	
SAR	SAR	meq0.5/ L0.5	NA	NA	Calculation

Notes:

1. Methods for Chemical Analysis of Water and Wastes. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-CIHL), EPA-600/4-79-020. Revised March 1983 and 1979 where applicable.
2. Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.
3. Bordner, R.H., and J.A. Winter, eds. 1978. "Microbiological Methods for Monitoring the Environment, Water and Waste." Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency. EPA-600/8-78-017.
4. Association of Official Analytical Chemists, Official Methods of Analysis (AOAC). 1990 15th Edition. All methods cited in this appendix are recommended methods. Other comparable methods yielding the same interpretive results are acceptable unless otherwise stated in the Wastewater-Land Application Permit.
5. A measure of inorganic TDS in wastewater is important in order to calculate total salt loading to a site and predict down-gradient ground water concentrations. Estimates of inorganic TDS can be made by subtracting VDS from TDS to obtain Non-Volatile Dissolved Solids (NVDS). Major ions may also be summed to estimate this parameter.

7.7.9 Crop Monitoring and Yield Estimation Supplemental Information

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7.7.9.1 Crop Nutrient Concentration Values

Table 7-30 provides estimated nitrogen contents of the harvested portion of selected crops and vegetables. These values are approximate; actual site values will vary due to crop maturity, crop variety, climate (particularly water stress), and general nutrition status of crop.†

Table 7-30. Crop Nutrient Concentration Values.

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
<u>Cereal and oil crops</u>							
Barley, grain	1	2.10	1.90-2.30	Bu	14	0.87	0.78-0.95
Straw	1	0.73	0.58-0.88	Ton	10	13	10-16
Barley	5	--	--	Bu	11	--	0.9
Barley	6	--	--	Bu	--	--	1.5 (for 100 bu/ac yield)
Corn, Grain, Shelled	1	1.55	1.35-1.75	Bu	15	0.73	0.64-0.83
Silage	1	1.25	1.10-1.45	Ton	70	7.2	6.6-8.7
Corn, Field for Grain	5	--	--	Bu	13	--	0.8
Corn, Grain	6	--	--	Bu	--	--	1.3 – 1.5 (as yield varies from 200 to 100 bu/ac)
Oat, grain	1	2.20	1.95-2.50	Bu	14	0.61	0.54-0.69
Straw	1	0.70	0.55-0.85	Ton	10	13	9-15
Oats	5	--	--	Bu	11	--	0.6
Oats	6	--	--	Bu	--	--	1.5 (for 100 bu/ac yield)
Rice, grain	1	1.40	1.05-1.65	Bu	14	0.54	0.41-0.64
Straw	1	0.65	0.50-0.80	Ton	10	12	9-14
Rye, grain	1	2.20	2.00-2.40	Bu	14	1.05	0.95-1.2
Straw	1	0.50	0.35-0.65	Ton	10	9	6-12

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Sorghum, grain	1	1.65	1.45-1.80	Bu	14	0.80	0.70-0.87
Soybean, grain	1	6.50	6.10-6.90	Bu	15	3.3	3.1-3.5
Straw	1	0.85	0.70-1.00	Ton	10	15	13-18
Sunflower, seed Oil type	1	2.70	2.20-3.20	Ton	10	49	40-58
Confection	1	3.20	2.80-3.60	Ton	10	58	50-65
Wheat grain, Hard red winter	1	2.30	2.05-2.50	Bu	14	1.2	1.1-1.3
Soft red winter	1	2.10	1.85-2.30	Bu	14	1.1	0.95-1.20
Soft white winter	1	1.80	1.60-2.00	Bu	14	0.95	0.80-1.05
Hard red spring	1	2.60	2.35-2.85	Bu	14	1.35	1.20-1.50
Straw	1	0.65	0.40-0.85	Ton	10	11	7-15
Wheat	5	--	--	Bu	11	--	1.2
Wheat	6			Bu			2.32 (for 100 bu/ac yield)
<u>Forage crops</u>							
Alfalfa, Hay, sun-cured Vegetative	1	3.30	2.80-3.80	Ton	15	56	48-65
Early bloom	1	3.05	2.55-3.55	Ton	15	52	43-60
Mid bloom	1	2.75	2.25-3.25	Ton	15	47	38-55
Full bloom	1	2.50	2.00-3.00	Ton	15	43	34-51
Green chop Vegetative	1	3.55	3.05-4.05	Ton	75	18	15-20

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Early bloom	1	3.15	2.65-3.65	Ton	75	16	13-18
Mid bloom	1	2.90	2.40-3.40	Ton	75	15	12-17
Full bloom	1	2.60	2.10-3.10	Ton	75	13	10-16
Alfalfa Hay	5	--	--	Ton	10	--	50.4
Alfalfa, Green Chop	5	--	--	Ton	75	--	14
Alfalfa Hay	6	--	--	Ton	--	--	53.3 (for 6 ton/ac yield)
Bermudagrass Hay, sun-cured Vegetative	1	2.50	1.90-3.10	Ton	15	43	32-53
Early to mid bloom	1	1.70	1.30-2.10	Ton	15	29	22-36
Full bloom to mature	1	1.10	0.80-1.40	Ton	15	19	14-24
Green chop Vegetative	1	2.75	2.10-3.40	Ton	75	14	11-17
Early to mid bloom	1	1.90	1.40-2.40	Ton	75	10	7-12
Full bloom to mature	1	1.25	0.90-1.60	Ton	75	6	5-8
Birdsfoot trefoil Hay, early bloom	1	3.10	2.60-3.60	Ton	15	53	44-61
Mid to full bloom	1	2.20	1.90-2.50	Ton	15	37	32-43
Green chop Early bloom	1	3.20	2.70-3.70	Ton	75	16	14-19
Mid to full bloom	1	2.30	1.95-2.65	Ton	75	12	10-13
Bluegrass, Kentucky	1	1.75	1.40-2.00	Ton	15	30	24-34

		N (Dry matter basis)				N harvested \pm	
Crop Description	Data Source	Common value	General range	Unit of measure	Moisture content of unit	Common value	General range
			----- % -----			%	----lb N/unit ---
Hay, sun-cured Mid bloom							
Mature	1	1.00	0.85-1.15	Ton	15	17	15-20
Hay, green chop Mid bloom	1	2.00	1.60-2.40	Ton	75	10	8-12
Mature	1	1.05	0.90-1.20	Ton	75	5	4-6
Bluestem Early bloom	1	1.40	1.10-1.70	Ton	20	22	18-27
Full bloom	1	1.10	0.90-1.30	Ton	20	18	14-21
Mature	1	0.70	0.60-0.80	Ton	20	11	10-13
Bromegrass, smooth, Hay, sun-cured Vegetative	1	3.05	2.60-3.50	Ton	15	52	44-60
Early bloom	1	2.10	1.75-2.45	Ton	15	36	30-42
Mid to late bloom	1	1.80	1.40-2.20	Ton	15	31	24-37
Mature	1	0.95	0.80-1.10	Ton	15	16	14-19
Hay, green chop Vegetative	1	3.35	2.85-3.85	Ton	75	17	14-19
Early bloom	1	2.25	1.90-2.60	Ton	75	11	9-13
Mid to late bloom	1	1.80	1.50-2.20	Ton	75	9	8-11
Mature	1	0.95	0.80-1.10	Ton	75	5	4.6
Bromegrass	6	--	--	Ton	--	--	60 (for a 6 ton/ac yield)
Clover Alsike Hay	1	2.40	2.05-2.75	Ton	15	41	35-47

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Green chop	1	2.75	2.35-3.15	Ton	75	14	12-16
Clover Hay	2, 3	--	--	Ton	15	--	41
Crimson Hay	1	2.65	2.25-3.05	Ton	15	45	38-52
Green chop	1	2.75	2.35-3.15	Ton	75	14	12-16
Ladino Hay	1	3.50	3.00-4.00	Ton	15	60	51-68
Green chop	1	4.00	3.50-4.50	Ton	75	20	17-23
Red, hay, sun-cured Late vegetative	1	3.35	2.85-3.85	Ton	15	57	49-66
Early to mid bloom	1	2.50	2.10-2.90	Ton	15	42	36-49
Full bloom	1	2.35	1.95-2.75	Ton	15	40	33-47
Red, green chop Late vegetative	1	3.40	2.90-3.90	Ton	75	17	15-20
Early to mid bloom	1	2.60	2.20-3.00	Ton	75	14	11-15
Full bloom	1	2.40	2.00-2.80	Ton	75	12	10-14
Sweet, hay	1	2.65	2.25-3.05	Ton	15	45	38-52
Green chop	1	2.90	2.50-3.30	Ton	75	15	13-17
White, hay	1	3.40	2.90-3.90	Ton	15	58	49-66
Green chop	1	4.00	3.50-4.50	Ton	75	20	18-23
Corn, silage	1	1.25	1.10-1.45	Ton	70	7.5	6.6-8.7
Corn, silage	5	--	--	Ton	72	--	7.1

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Corn, silage	6	--	--	Ton	--	--	6.25 (for 32 ton/ac yield)
Fescue, tall Hay, late vegetative	1	2.70	2.20-3.20	Ton	15	46	37-54
Mid bloom	1	1.50	1.20-1.80	Ton	15	26	20-31
Mature	1	1.00	0.80-1.20	Ton	15	17	14-20
Green chop Late vegetative	1	2.90	2.30-3.50	Ton	75	15	12-18
Mid bloom	1	1.70	1.40-2.00	Ton	75	9	7-10
Mature	1	1.10	0.90-1.30	Ton	75	6	5-7
Fescue, tall	2, 3	--	--	Ton	15	--	46
Grass Silage	5	--	--	Ton	75	--	14
Grass Hay	6	--	--	Ton	--	--	60 (for 4 ton/ac yield)
Meadow Foxtail	6	--	--	Ton	--	--	60 (for 6 ton/ac yield)
Orchardgrass Hay, late vegetative	1	2.40	1.90-2.90	Ton	15	41	32-49
Mid bloom	1	1.60	1.30-1.90	Ton	15	27	22-32
Mature	1	1.20	1.00-1.40	Ton	15	20	17-24
Green chop Late vegetative	1	2.50	2.00-3.00	Ton	75	13	10-15
Mid bloom	1	1.70	1.40-2.00	Ton	75	9	7-10
Mature	1	1.20	1.00-1.40	Ton	75	6	5-7
Orchardgrass	2, 3	--	--	Ton	15	--	41
Orchardgrass	6	--	--	Ton	--	--	60 (for 6 ton/ac yield)

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Peanut, hay	1	1.85	1.50-2.20	Ton	15	31	26-37
Reed Canarygrass	6	--	--	Ton	--	--	60 (for 6 ton/ac yield)
Ryegrass Hay, late vegetative	1	1.85	1.50-2.20	Ton	15	31	26-37
Mid bloom	1	1.30	1.00-1.60	Ton	15	22	17-27
Green chop Late vegetate	1	2.00	1.60-2.40	Ton	75	10	8-12
Mid bloom	1	1.40	1.10-1.70	Ton	75	7	6-9
Sorghum, silage	1	1.00	0.70-1.30	Ton	74	5.2	3.5-6.8
Sorghum-sudan Green chop Immature	1	2.65	1.90-3.45	Ton	82	9.5	6.8-12
Mid-mature	1	1.40	1.00-1.80	Ton	77	6.4	4.6-8.3
Silage	1	1.50	0.95-2.05	Ton	77	6.9	4.5-9.5
Timothy Hay, sun-cured Vegetative	1	2.25	1.90-2.60	Ton	15	38	32-44
Early to mid bloom	1	1.55	1.30-1.90	Ton	15	26	22-32
Late bloom	1	1.20	1.00-1.40	Ton	15	20	17-24
Mature	1	0.95	0.80-1.10	Ton	15	16	14-19
Hay, green chop Vegetative	1	2.30	1.95-2.65	Ton	75	12	10-13
Early to mid bloom	1	1.70	1.35-2.00	Ton	75	9	7-10
Late bloom	1	1.25	1.05-1.45	Ton	75	6	5-7
Mature	1	0.95	0.80-1.10	Ton	75	5	4-6

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Vetch Common Hay, early bloom	1	3.60	3.10-4.10	Ton	15	61	53-70
Full bloom	1	2.90	2.50-3.30	Ton	15	49	43-56
Green chop Early bloom	1	3.70	3.10-4.20	Ton	75	19	16-21
Full bloom	1	3.00	2.60-3.40	Ton	75	15	13-17
Hairy fresh Mid bloom	1	3.70	3.10-4.20	Ton	75	19	16-21
Wheatgrass, crested Hay, early bloom	1	1.60	1.30-1.90	Ton	20	26	21-30
Full bloom	1	1.40	1.10-1.70	Ton	20	22	18-27
Mature	1	0.60	0.50-0.70	Ton	20	10	8-11
Wheatgrass, crested	2, 3	--	--	Ton	20	--	26
<u>Fiber and miscellaneous crops</u>							
Flax, seed	1	3.80	3.30-4.30	100 lb (1 cwt)	7	3.5	3.1-4.0
Hay	1	1.85	1.50-2.20	Ton	15	31	26-37
Potato, white tubers	1	1.60	1.20-1.90	100 lb (1 cwt)	75	0.4	0.3-0.5
Potato	6	--	--	100 lb (1 cwt)	--	--	0.55 (for a 400 cwt yield)
Rangeland	5	--	--	--	--	--	24
Sugarbeet Tops w/crown	1	2.10	1.80-2.30	--	82	7.6	6.5-8.3

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Roots w/o crown	1	0.80	0.60-0.95	Ton	77	3.7	2.8-4.4
Tops w/o crown	1	2.50	2.20-2.80	Ton	82	9.0	7.9-10.1
Roots w/crown	1	1.10	0.90-1.30	Ton	77	5.1	4.1-6.0
Sunflower, seed Oil type	1	2.70	2.20-3.20	Ton	10	49	40-58
Confection	1	3.20	2.80-3.60	Ton	10	58	50-65
Trees	4						80 - 220
<u>Vegetable crops</u>							
Bean, snap, pods	1	3.00	2.50-3.50	Ton	87	7.8	6.5-9.0
Dry bean seed	1	4.00	3.50-4.50	100 lb (1 cwt)	10	3.6	3.2-4.1
Tops	1	3.50	3.00-4.00	Ton	85	11	9-13
Onion, bulbs	1	2.20	1.90-2.50	Ton	90	4.4	3.8-5.0
Pea, seed only	1	4.20	3.50-4.70	Ton	80	17	14-19
Vine-no pods	1	2.00	1.50-2.50	Ton	75	10	8-13
Pepper, sweet green	1	2.30	1.90-2.70	Ton	92	3.7	3.0-4.3
Squash, summer	1	3.10	2.70-3.50	Ton	92	5.0	4.3-5.6
Winter	1	2.10	1.70-2.50	Ton	88	5.0	4.1-6.0
Sweet corn, stover	1	1.30	1.10-1.50	Ton	70	7.8	6.6-9.0
Ears with husks	1	1.60	1.40-1.80	Ton	73	8.6	7.6-9.7
Sweet potato, root	1	1.10	0.90-1.30	Ton	72	6.2	5.0-7.3

Crop Description	Data Source	N (Dry matter basis)			Moisture content of unit	N harvested†	
		Common value	General range	Unit of measure		Common value	General range
			----- % -----			%	----lb N/unit ---
Tomato	1	2.70	2.30-3.10	Ton	94	3.2	2.8-3.7
<u>Tree and fruit crops</u>							
Apple	1	0.35	0.25-0.45	Ton	82	1.3	0.9-1.6
Almond, with shell	1	3.30	3.00-3.60	Ton	15	56	51-61
Cherry	1	1.15	1.00-1.30	Ton	82	4.1	3.6-4.7
Grape	1	0.60	0.50-0.70	Ton	80	2.4	2.0-2.8
Peach	1	1.00	0.80-1.20	Ton	88	2.4	1.9-2.9
Pear	1	0.40	0.30-0.50	Ton	82	1.4	1.1-1.8
Pecan, with shell	1	2.80	2.50-3.10	Ton	15	48	43-53
Strawberry	1	1.35	1.10-1.60	Ton	91	2.4	2.0-2.9

†Percent N and N harvested will generally be above the common value for crops grown on N-rich soils (luxury amounts of manure, fertilizer, etc.) and for crops grown in water-stress conditions (low dry matter production); percent N and harvested N will generally be below the common value for crops grown in N poor soils (low N inputs (and for crops with above-average dry matter production (good rainfall years, irrigation, etc.)

‡CHh as defined in Chapter 12 by Pierce et al., is the N removed in the harvested biomass.

Data Sources:

- 1) Follett et al. 1991;
- 2) Fonnesbeck et al., 1984;
- 3) Part 651, Agricultural Waste Management Field Handbook
- 4) From various references for poplars, other deciduous trees, conifers, and woodlands; Note: Alternative uptake values provided by a qualified silviculturist are acceptable.
- 5) 1992 Census of Agriculture, refer to the following website: <http://www.nhq.nrcs.usda.gov/land/pubs/nlapp1a.html>
- 6) DEQ 1988 WLAP Guidelines. Adapted from Kelling, K.A., and A.E. Peterson and the Land-Applied Wastewater Technical Advisory Committee

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8. Not Used at This Time

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